

UC-NRLF



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HERING

CONDENSED LIST.

Ap. means within 2%.

Physical Quantities, Relations, Dimensional Formulas, etc., p. 18-26

Lengths: complete tables, p. 30-34

1 mil = 0.025 40 mm. Ap. $\frac{1}{40}$

1 mm. = 39.37 mils. Ap. 40

1 cm. = 0.393 7 inch. Ap. $\frac{1}{10}$

1 inch = 2.540 centimeters. Ap. $\frac{1}{10}$

1 foot = 0.304 8 meter. Ap. $\frac{3}{10}$

1 yard = 0.914 4 meter. Ap. $\frac{9}{10}$ or $\frac{10}{11}$

1 meter = 39.37 inches. Ap. 40

" = 3.281 feet. Ap. $\frac{1}{10}$

" = 1.094 yards. Ap. $\frac{1}{10}$

1 kilometer = 3 281. feet. Ap. $\frac{1}{10}$ × 10 000

" = 1 094. yards. Ap. 1 100

" = 0.621 4 mile. Ap. $\frac{5}{8}$

1 mile = 5 280. feet. Ap. 5 300

" = 1 760. yards. Ap. $\frac{7}{4}$ × 1 000

" = 1.609 km. Ap. add $\frac{1}{10}$

1 knot = 1.853 kilometers. Ap. $\frac{1}{10}$

" = 1.152 miles. Ap. add $\frac{1}{4}$

Inches in fractions, decimals, millimeters and feet, p. 35-38

Digit conv. tables (1 to 100), p. 39-40

Surfaces: complete tables, p. 41-44

1 circular mil = 0.000 506 7 sq. mm.

Ap. $\frac{1}{2}$ ÷ 1 000

1 sq. mm. = 1 974. circ. mils. Ap. 2 000

1 sq. cm. = 0.155 0 sq. inch. Ap. $\frac{2}{13}$

1 sq. inch = 1 273 240. circ. mils

" = 6.452 sq. cm. Ap. $\frac{6}{12}$

1 sq. ft. = 0.092 90 sq. m. Ap. $\frac{1}{12}$ ÷ 10

1 sq. yd. = 0.836 1 sq. meter. Ap. $\frac{5}{6}$

1 sq. m. = 10.76 sq. ft. Ap. $\frac{12}{11}$ × 10

" = 1.196 sq. yds. Ap. add $\frac{1}{5}$

1 acre = 43 560. sq. feet

" = 0.404 7 hectare. Ap. $\frac{4}{16}$

1 hectare = 2.471 acres. Ap. $\frac{1}{14}$

" = 0.003 861 sq. mile

1 sq. km. = 247.1 acres. Ap. $\frac{1}{4}$ × 1 000

" = 0.386 1 sq. mile. Ap. $\frac{1}{26}$

1 sq. mile = 640. acres

" = 2.590 sq. km. Ap. 26 ÷ 10

Digit conversion tables, p. 44

Volumes: complete tables p. 46-55

1 cb. cm. = 0.061 02 cb. in. Ap. $\frac{1}{100}$

1 cb. in. = 16.39 cb. cm. Ap. $\frac{100}{6}$

1 pint = 28.875 cb. in. Ap. $\frac{2}{7}$ × 100

" = 0.473 2 liter. Ap. $\frac{1}{21}$ × 10

1 quart = 0.946 4 liter. Ap. sub. $\frac{1}{20}$

1 liter = 61.02 cb. inches. Ap. 60

" = 1.057 quarts. Ap. add $\frac{1}{20}$

" = 0.035 31 cb. ft. Ap. $\frac{7}{2}$ ÷ 100

1 gal. (U. S.) = 231. cb. inches.

" = 3.785 liters. Ap. $\frac{3}{8}$ × 10

" = 0.133 7 cb. ft. Ap. $\frac{4}{3}$ ÷ 10

" (Brit.) = 4.546 liters. Ap. $\frac{4}{12}$

1 cb. ft. = 28.32 liters. Ap. $\frac{2}{7}$ × 100

" = 7.481 gal. (U. S.). Ap. $\frac{3}{10}$

1 bushel (U. S.) = 1.244 cb. ft. Ap. $\frac{1}{4}$

" = 0.352 4 hectoliter. Ap. $\frac{7}{2}$ ÷ 10

1 hectoliter = 26.42 gals. (U. S.) Ap. $\frac{8}{3}$ × 10

1 cb. yd. = 0.764 6 cb. meter. Ap. $\frac{3}{4}$

1 cb. m. = 35.31 cb. ft. Ap. $\frac{7}{2}$ × 10

" = 1.308 cb. yds. Ap. $\frac{1}{12}$

Digit conversion tables, p. 51

Weights: complete table, p. 57-61

1 grain = 64.80 mg. Ap. 65

1 gram = 15.43 grains. Ap. $\frac{15}{2}$

" = 0.035 27 oz. Ap. $\frac{7}{2}$ ÷ 100

1 ounce = 28.35 grams. Ap. $\frac{2}{7}$ × 100

1 pound (av.) = 0.453 6 kg. Ap. $\frac{9}{20}$

1 kilogram = 35 27 oz. Ap. $\frac{7}{2}$ × 10

" = 2.205 pounds. Ap. $\frac{2}{5}$

1 short ton = 0.907 2 met. ton. Ap. subtr. $\frac{1}{10}$

do. = 0.892 9 long ton. Ap. subtr. $\frac{1}{10}$

1 metric ton = 1.102 short tons.

Ap. add $\frac{1}{10}$

do. = 0.984 2 long ton. Ap. 1

1 long ton = 1.12 short tons. Ap. $\frac{1}{10}$

" = 1.016 met. tons. Ap. 1

Digit conversion tables, p. 59

Weights and Lengths; Wt. of Bars: complete table, p. 62-63

1 lb. per mile = 0.281 8 kg. per km.

Ap. $\frac{2}{7}$

1 kg. per kilometer = 3.548 lbs. per mile. Ap. $\frac{7}{2}$

1 lb. per yard = 0.496 1 kg. per meter. Ap. $\frac{1}{2}$

1 kg. per meter = 2.016 lbs. per yard. Ap. 2

do. = 0.672 0 lb. per ft. Ap. $\frac{2}{3}$

1 lb. per ft. = 1.488 kg. per m. Ap. $\frac{3}{2}$

Pressures: complete table, p. 64-67

1 lb. per sq. ft. = 4.882 kg. per sq. meter. Ap. $\frac{4}{10}$

1 ft. water column = 62.43 lbs. per sq. foot. Ap. $\frac{500}{8}$

do. = 0.029 50 atm. Ap. $\frac{3}{100}$

1 lb. per sq. in. = 0.070 31 kg. per sq. cm. Ap. $\frac{7}{100}$

do. = 0.068 04 atmosphere. Ap. $\frac{2}{30}$

1 kg. per sq. cm. = 14.22 lbs. per sq. in. Ap. $\frac{100}{7}$

do. = 0.967 8 atmosphere. Ap. subtr. $\frac{1}{30}$

1 atm. = 14.70 lbs. per sq. in. Ap. $\frac{4}{3}$

" = 1.033 kg. per sq. cm. Ap. add $\frac{1}{30}$

Digit conversion tables, p. 67

Weights and Volumes: complete table, p. 68-69

1 lb. per cb. yd. = 0.593 3 kg. per cubic meter. Ap. $\frac{1}{10}$

1 kg. per cb. meter = 1.686 lbs. per cb. yd. Ap. $\frac{1}{10}$

do. = 0.062 43 lb. per cb. ft. Ap. $\frac{5}{80}$

1 lb. per cb. ft. = 16.02 kg. per cb. meter. Ap. $\frac{80}{5}$

Weights of Water: complete table, p. 70

1 cb. cm. = 0.035 27 oz. Ap. $\frac{7}{200}$

1 cb. inch = 16.39 grams. Ap. $\frac{100}{6}$

" = 0.578 0 ounce. Ap. $\frac{4}{7}$

1 pint = 1.043 pounds. Ap. add $\frac{1}{20}$

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1 liter = 2.205 pounds. Ap. $\frac{22}{10}$	1 met. hp. = 75.00 kilogram-meters per sec. Or $\frac{3}{4} \times 100$
1 cb. ft. = 62.43 pounds. Ap. $\frac{5}{8} \times 100$	do. = 0.986 3 hp. Ap. 1
“ = 28.32 kilograms. Ap. $\frac{200}{7}$	do. = 0.735 4 kw. Ap. $\frac{22}{3} \div 10$
1 cb. yd. = 1 686 lbs. Ap. $\frac{1}{6} \times 10\ 000$	1 hp. = 33 000 ft.-lbs. per min. Ap. $\frac{1}{3} \times 100\ 000$
“ = 764.6 kg. Ap. $\frac{3}{4} \times 1\ 000$	“ = 1.014 metric hp. Ap. 1
1 cb. meter = 2 205 pounds	“ = 0.745 7 kilowatt. Ap. $\frac{3}{4}$
“ = 0.984 2 ton (long). Ap. 1	1 kw. = 1.360 m. hp. Ap. add $\frac{1}{3}$
Volumes of Water: complete table, p. 71	“ = 1.341 hp. Ap. add $\frac{1}{3}$
1 gram = 0.061 02 cb. in. Ap. $\frac{9}{100}$	Digit conversion tables, p. 82
1 ounce = 28.35 cb. cm. Ap. $\frac{3}{4} \times 100$	Forces: complete table, p. 83
1 lb. = 27.68 cb. in. Ap. $\frac{1}{4} \times 10$	1 dyne = 1.020 milligrams. Ap. 1
“ = 0.453 6 liter. Ap. $\frac{5}{11}$	1 gram = 980.6 dynes. Ap. 1 000
“ = 0.016 02 cb. foot. Ap. $\frac{8}{5} \div 100$	1 pound = 444 791 dynes
1 kilogram = 61.02 cb. in. Ap. 60	Moments of Inertia and of Momentum, p. 84
“ = 0.035 31 cb. ft. Ap. $\frac{7}{2} \div 100$	Linear Velocities: complete table, p. 85-86
Energy; Work; Heat: complete table, p. 74-77	1 km. per hr. = 16.67 met. per min. Ap. $\frac{1}{6} \times 100$
1 joule = 0.737 6 ft.-lb. Ap. $\frac{3}{4}$	1 ft. per sec. = 0.681 8 mile per hour. Ap. 68 $\div$ 100
“ = 0.238 9 small calorie.	1 mile per hour = 1.467 ft. per second. Ap. $\frac{1}{3}$
“ = 0.102 0 kg.-met. Ap. $\frac{1}{10}$	1 meter per sec. = 3.6 km. per hour
1 ft.-lb. = 1.356 joules. Ap. $\frac{4}{3}$	Angular Velocities, p. 86
“ = 0.323 9 small cal. Ap. $\frac{18}{40}$	Frequency, p. 86
“ = 0.138 3 kg.-met. Ap. $\frac{7}{50}$	Linear Accelerations: complete table, p. 88
“ = 0.001 285 thermal unit. Ap. $\frac{9}{4} \div 1000$	Gravity = 32.17 ft. per sec. per sec. Ap. 32
1 kg.-m. = 9.806 joules. Ap. 10	Gravity = 9.806 m. per s. per s. Ap. 10
“ = 7.233 ft.-lbs. Ap. $\frac{80}{11}$	Angular Accelerations, p. 88
“ = 2.342 g.-calories. Ap. $\frac{7}{3}$	Angles: complete table, p. 89
1 ther. unit = 1 055 joules. Ap. $\frac{2100}{2}$	1 deg. = 0.017 45 radian. Ap. $\frac{7}{4} \div 100$
“ = 778.1 ft.-lb. Ap. $\frac{7000}{9}$	1 radian = 57.30 degrees
“ = 107.6 kg.-met. Ap. 108	1 right angle = 1.571 radians. Ap. $\frac{1}{4}$
“ = 0.252 0 kg.-cal. Ap. $\frac{1}{4}$	Solid angles, p. 89
1 watt-hour = 2 655 ft.-lbs. Ap. $\frac{8000}{3}$	Grades: complete table, p. 90-91
“ = 367.1 kg.-met. Ap. $\frac{1100}{3}$	1 foot per mile = 0.018 94%
“ = 0.860 0 kg.-gal. Ap. $\frac{9}{7}$	1% = 52.80 feet per mile
1 cal. (kg.) = 4 186 joules. Ap. 4 200	Conversion table 1 to 15%, p. 92
“ = 3 088 ft.-lbs. Ap. 3 100	Time, p. 94
“ = 426.9 kg.-met. Ap. $\frac{3000}{7}$	Discharges; Flow of Water; Irrigation Units, p. 95
“ = 3.968 ther. units. Ap. 4	1 miner's inch = 1.5 cb. ft. per min.
“ = 1.163 watt-hrs. Ap. $\frac{7}{6}$	1 acre-foot = 325 851. gallons
1 met. hp.-hr. = 1 952 910 ft.-lbs. = 270 000 kg.-met.	Electric and Magnetic Units:
1 hp.-hr. = 1 980 000 foot-pounds = 273 745 kilogram-meters	Mean, effec. and max. values, p. 97
1 kw.-hr. = 2 655 403 foot-pounds = 367 123 kilogram-meters	Resistance, Impedance, Reactance, p. 99
Digit conversion tables, p. 77	1 Brit. Assn. unit = 0.986 7 ohm. Ap. subtr. 1%
Relations between Torque and Energy, p. 78	1 ohm = 1.014 Brit. Assn. units. Ap. add 1%
Traction Energy, p. 78	Resistance and Length, p. 101
1 ton (met.)-km. = 0.684 9 ton (sh.)-mile. Ap. $\frac{9}{13}$	Resistance and Cross-section, p. 101
1 ton (sh.)-mile = 1.460 ton (met.)-kilometer. Ap. $\frac{1}{3}$	Resistivity; Specific Resistance, complete table, p. 103-4
Tractive Force, p. 78	1 ohm, circ. mil, ft., unit = 0.001 662 ohm, sq. mm., m., unit. Ap. $\frac{1}{600}$
1 lb. per ton (sh.) = 0.500 0 kilogram per ton (met.)	1 ohm, sq. mm., m., unit = 601.5 ohm, circ. mil, foot units
1 kg. per ton (met.) = 2.000 pounds per ton (short)	Resistivity of pure copper:
Power: complete table, p. 80-82	= 10.03 ohm, circ. mil, foot units
1 watt = 44.26 ft.-lbs. per minute. Ap. $\frac{4}{5} \times 100$	= 0.016 67 ohm, sq. mm., m., unit
do. = 14.33 gram-cal. per minute. Ap. $\frac{1}{4} \times 100$	
do. = 6.119 kg.-met. per minute. Ap. 6	

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Resistivity of mercury:

=565.9 ohm, circ. mil, foot units

=0.940 7 ohm, sq. mm., meter unit

Conductance, Admittance, Susceptance, p. 105

Conductivity, Specific Conductance, complete table, p. 107

1 mercury unit=0.017 72 copper unit

1 copper unit=55.76 mercury units

Electromotive Force, complete table, p. 109-111

1 volt=0.981 0 Weston cell at 20° C.

Ap. subtr. 2%

" =0.697 4 Clark cell 15°. Ap. $\frac{7}{10}$

1 Weston cell at 20° C.:

=1.019 4 volts Ap. add 2%

=0.710 9 Clark cell at 15° C. Ap. $\frac{5}{4}$

1 Clark cell 15°=1.434 volts. Ap. $\frac{1}{97}$

" " =1.407 Weston cells at 20°. Ap. $\frac{7}{5}$

E.M.F. of Clark and Weston cells at different temperatures, p. 111

Current, p. 113

Current Density, complete table, p. 114-115

1 ampere per square inch:

=0.155 0 amp. per sq. cm. Ap. $\frac{2}{13}$

1 ampere per square centimeter:

=6.452 amp. per sq. in. Ap. $6\frac{1}{2}$

1 ampere per square millimeter:

=0.000 506 7 ampere per circular mil. Ap. $\frac{1}{2}+100$ 0

1 ampere per circular mil:

=197 4. amp. per sq. mm. Ap. 2000

Quantity; Charge, p. 116

Capacity, p. 117

Inductance, p. 119

Time Constant, p. 120

Frequency: complete table, p. 121

Frequency=0.159 2×angular veloc.

Angular velocity=6.283×frequency

Kinetic Energy of a Current, p. 122

Electrical Energy, p. 123

(see also under Energy, p. 74)

Electrical Power, p. 125

(see also under Power, p. 80)

Electrochemical Equiv., p. 126

Ionic charge=96 539, coulombs

Electrolytic Deposits, p. 126-7

1 pound per day=0.182 6 ton (short) per year. Ap. $1\frac{1}{3}+10$

1 kg. per day=0.365 3 met. ton per year. Ap. $1\frac{1}{3}+10$

Electrochemical Energy: complete table, p. 129

Volts=kg.-calories per gram-molecule×0.043 36. Ap. $\frac{3}{40}$

Magnetic Reluctance, p. 129

Oersted=gilberts+maxwells

" =ampere-turns×1.257+maxwells

Magnetic Reluctivity, p. 130

Magnetic Permeance, p. 131

Magnetic Permeability, p. 132

=gausses in iron÷gausses in air

Magnetic Susceptibility, p. 132

Magnetomotive Force: complete table, p. 133-4

1 gilbert=0.795 8 ampere-turns. Ap. subtr. $\frac{1}{5}$

1 amp.-turn=1.257gilb't. Ap. add $\frac{1}{4}$

Gilberts=maxwells×oersteds

Magnetizing Force, p. 136-7

1 amp.-turn per inch=0.494 7 gilbert per centimeter. Ap. $\frac{1}{2}$

1 gilbert per cm.=2.021 amp.-turn per inch. Ap. 2

Magnetic Flux, p. 138-9

Maxwells=gausses×sq. centimeters

" =gilberts÷oersteds

Magnetic Flux Density: complete table, p. 141-2

1 inch-gauss=0.155 0 gauss. Ap. $\frac{3}{13}$

1 gauss=6.452 inch-gausses. Ap. $6\frac{1}{2}$

Gausses=maxwells÷sq. centimeters

Magnetic Moment, p. 142

Intensity of Magnetization, 142

Magnetic Energy, p. 143

Magnetic Power, p. 144

Photometric Units:

Intensity of Light; Candle Power: complete table, p. 146

1 hefner=0.88 English candle

1 English candle=1.14 hefners

Flux of Light; Spherical or Hemisph. Candle Power, 147

Illumination: compl. table, p. 148

1 met.-cp.=0.081 8 ft.-cp. Ap. $\frac{1}{12}$

1 ft.-cp.=12.2 met.-cp (hefners)

Brightness of Source, p. 148

Quantity of Light, p. 149

Light Efficiency, p. 149

Thermometer Scales:

Reduction factors, p. 150

Readings in:

C.°=(F.°-32)× $\frac{5}{9}$

F.°=(C.°× $\frac{9}{5}$)+32

Scales: Centigrade, Fahrenheit!

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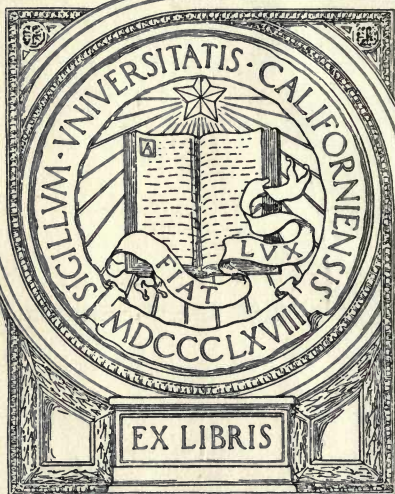
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ETC., ETC. WITH THEIR ACCURATE AND
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TIONS, ETC., ETC.

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UNITED STATES.

CONVENIENTLY ARRANGED FOR
ENGINEERS, PHYSICISTS, STUDENTS, MERCHANTS, ETC.

BY

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President Engineers' Club of Philadelphia ;
Delegate to International Congresses ; etc.*

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"I look upon our English system as a wickedly brain-destroying piece of bondage under which we suffer. I say this seriously. I do not think any one knows how seriously I speak of it."—Sir WILLIAM THOMSON (now Lord Kelvin), Philadelphia, Sept. 24, 1884.

PREFACE.

THE present is the first of several volumes in preparation by the author, which are intended to contain collections of data conveniently arranged for ready reference. In this first volume, all the various measures used in practice, more especially by engineers and physicists, are given with their values in terms of as many of the others as they are likely to be converted into in practice; the reciprocals of these are also given, thus enabling every calculation involving the conversion of one measure into another to be reduced to a single, simple multiplication. Moreover, they are stated in such a form that errors due to dividing instead of multiplying are entirely avoided. It has been the intention to include every unit or measure used in practice, besides many that are now obsolete but are occasionally met with. The more usual foreign units or measures have also been added.

These conversion factors are not compiled, but have all been especially recalculated for this volume, under the direction of the author, from the exact legal values as far as such values existed, and from the very best, most standard, and most authoritative values obtainable, when no legal values existed. The greatest possible care was taken in selecting these fundamental values. They were obtained from the National Bureau of Standards, the Director of the Nautical Almanac, the International Geodetic Association, the U. S. Coast and Geodetic Survey, the U. S. Treasury Department, the adoptions and recommendations of international congresses and national societies, standard works of reference, and personal authorities, preference in the few cases of disagreement being generally given in the order named. The authority for each fundamental value is given. As all the conversion factors were calculated from the same set of fundamental values, they are all consistent with each other, forming a single, interconvertible, uniform system. It is believed that this is the first time such a complete set of conversion factors of all measures has been published, based on the accurate legal standard values. It is also believed to be the first complete collection of all the electric, magnetic, and photometric units, together with their interrelations, that has been published in convenient tabular form for ready reference.

Accuracy, completeness, and convenience for ready reference were the chief aims in the preparation of these tables. The calculations were very carefully made, in many cases by two entirely different methods, and the resulting values were checked and cross-checked, often several times. For most of the values a final comparison was made between the electrotyped plates and the original calculation sheets. All values marked with asterisks were checked by the original authorities after the pages were electrotyped. It is therefore believed that there are no errors, but should any errors or omissions be found, the author would greatly appreciate being notified of them, as it is the intention to have the values correct and the collection complete, so as to serve as a reliable standard of reference.

A new feature has been added in the form of convenient approximate values consisting often of only one and generally of only two digits. These digits have been so chosen that they reduce the calculation to the simplest possible; they will be found to suffice for most of the ordinary computations, being always correct within 2%. The correct logarithms have also been given for nearly all of the conversion factors.

Another new feature not generally found in tables of conversion factors is that the values of most of the compound units are given. This saves double, triple, or even more lengthy calculations, in which errors are likely to be made, as they often involve both multiplications and divisions.

A table of physical quantities has been added giving the derivation, symbols, dimensional formula, etc., of each; the table is similar to the one approved by the International Congress at Chicago, but includes many more quantities.

The usual method of giving tables of "Weights and Measures" has been entirely abandoned here as too cumbersome, inadequate, and entirely impracticable for giving numerous values each with its reciprocals; such tables are moreover quite unsuited for ready reference. The author has, instead, adopted a system in which all interconvertible units (like the mechanical, heat, and electrical units of energy, for instance) are given together in one table, and are there placed in the order of their size. This system is not only a more condensed and practical one, but is also far more convenient for ready reference.

The present tables are an extension and entire recalculation of the very much smaller ones published by the author about twenty years ago under the title of "Equivalents of Units of Measurement."

Unusual, foreign, and obsolete units, or those used for special trades, have been added as far as they were obtainable, and in every case their values are given in terms of the usual, legal, or modern units.

For some units, more particularly the electric, magnetic, photometric, etc., explanations have been added of the meaning, derivation, and proper use of the units, which are often incorrectly understood or applied. Some explanatory notes on the usual methods and accuracies of calculations are also given in the introduction.

The index has been made very complete, and in addition to this, attention is called to the Condensed List beginning on the inside cover-page, which contains the most frequently used values with page references to the others.

A comparison with other tables will show that many of the latter are not based on the legal standards of the country. It is not generally known, for instance, that the legal foot is derived from the meter and not from a standard yard. Many of these other tables are based on an unauthorized value of the meter in inches.

Although the accuracy adopted throughout, namely, six places of figures and seven of logarithms, may not always be warranted by the accuracy of some of the fundamental figures, yet it has been maintained uniform throughout these tables in order to enable changes to be made by mere proportion, when more accurate fundamental values become obtainable in the future.

The author takes pleasure in expressing his appreciation of the valuable assistance contributed by others, which has added greatly to the completeness and reliability of the information and makes much of it authoritative. He desires to express his obligations to the following: To the National Bureau of Standards, and in particular to its Director, Prof. S. W. Stratton, for very full and complete published and unpublished data concerning the values of the legal standards of this and other countries; also for his consent to allow the name of that Bureau to be added to these data, and for much other valuable information and assistance. To L. A. Fischer, Assistant Physicist of that Bureau for the laborious work of checking the correctness of many values of the conversion factors of the fundamental mechanical units. To Dr. F. A. Wolff, Assistant Physicist of that Bureau, for similar service in connection with the standard values of some of the electrical units. To Prof. Walter S. Harshman, Director of the Nautical Almanac, for his revision of the table of units of time. To Prof. Thomas Gray, author of the Smithsonian Physical Tables, for suggestions and recommendations concerning some of the derivational and dimensional formulas in the table of Physical Quantities. To Prof. W. S. Franklin for recommendations, suggestions, and a revision of those relations between the electrical and magnetic units which apply to varying currents. To Dr. Ed. L. Nichols for information concerning some of the standards of candle-power. To Dr. A. E. Kennelly for a revision of parts of the table of physical quantities. To the author's former assistant, Dr. E. F. Roeber, for his able work in mathematical physics and his reliable calculations of many of the values in the tables.

CARL HERING.

PHILADELPHIA, April, 1904.

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SYMBOLS AND ABBREVIATIONS

USED IN THE TABLES AND TEXT.

The page-numbers refer to the pages where the explanation or most important use is given.

- a* acceleration, 19
A acre, 43
A, a ampere, 15, 113
a are, 43
ah ampere-hour, 116
ap apothecary measures, 46, 57
Aprx approximate within 2%, 28, 96
atm atmosphere, 66
av avoirdupois weights, 57
a-t ampere-turns, 132
B magnetic induction, 140
B, b, B, b susceptance, 22, 104
B.A.U. British Association unit, 99
bbl barrel, 53
Brit. British or English, 30
BTU Board of Trade unit (kilowatt-hour), 77
BTU British thermal unit, 74, 75
bu bushel, 50
C, c, C, c capacity, electric, 23, 117
C, c coulomb, 15, 116
C° Centigrade degrees, 150
c cord, 54
Cal calorie, large, 76
cal calorie, small, 75
Cal/min calorie (large) per minute, 81
cal/min calorie (small) per minute, 80
cal/s calorie (small) per second, 81
cb cubic, 46
Ccm circular centimeter 42
Cft circular foot, 42
cg centigram, 57
C.G.S. or CGS centimeter-gram-second, 11
ch chain, 32
Cin circular inch, 42
circ. circular 41
cl centiliter, 52
cm centimeter, 30
cm² square centimeter, 42
cm³ cubic centimeter, 46
cm/s centimeter per second, 85
cm/s² centimeter per second per second, 88
CM circular mil, 41
Cmm circular millimeter, 41
cp candle power, 144, 146
cwt hundredweight, 58
d diameter, 41
dg decigram, 57
dkg decagram or dekagram, 59
dkl decaliter or dekaliter, 52
dkm decameter or dekameter, 32
dks decastere or dekastere, 54
dl deciliter, 47
dm decimeter, 30
dm² square decimeter, 42
dm³ cubic decimeter, 48
ds decistere, 53
dwt pennyweight, 59
dyne-cm dyne-centimeter (erg), 74
dyne/cm dyne per centimeter, 62
dyne/cm² dyne per square centimeter, 64
e base of Napierian logarithms, 171
e, e brightness of source of light, 16, 148
E, e, E, e electromotive force, 22, 108
E_t electromotive force at *t* degrees, 111
E, e ell, 32
E, E illumination, 16, 148
eff. effective value
elmg electromagnetic, 96
elst electrostatic, 96
e.m.f. electromotive force, 108
F° Fahrenheit degrees, 150
F farad, 15, 117
F, f force, 18
F magnetomotive force, 132
fl fluid measures, 52
ft foot or feet, 30
ft² square foot, 42
ft³ cubic foot, 49
ft-gr foot-grain, 74
ft-gr/s foot-grain per second, 80
ft-lb foot-pound, 74

- ft-lb/min foot-pound per minute, 80
 ft-lb/s foot-pound per second, 80
 ft/C foot per hundred, 90
 ft/ft foot per foot, 90
 ft/M foot per thousand, 90
 ft/min foot per minute, 85
 ft/ml foot per mile, 90
 ft/s foot per second, 85
 ft/s² foot per second per second, 88
 fur furlong, 32
 G, g, *G*, *g* conductance, 22, 104
 g acceleration of gravity, 171
 g gram, 58
 gal gallon, 49
 gi gill, 52
 gr grain, 57
 g-C gram-Centigrade heat unit, 75
 g-cm gram-centimeter, 74
 g-cm/s gram-centimeter per second, 80
 g/cm gram per centimeter, 62
 g/cm² gram per square centimeter, 64
 g/cm³ gram per cubic centimeter, 69
 g/dm² gram per square decimeter, 64
 g/h gram per hour, 127
 g/m gram per meter, 62
 g/min gram per minute, 127
 gr/in grain per inch, 62
 gr/in³ grain per cubic inch, 68
 H heat, 26
 H henry, 119
 H hydrogen, 126
 H magnetic flux density, 140
 H magnetizing force, 134
 h hour, duration, 94
^h hour, time of day, 93
 ha hectare, 43
 hg hectogram, 60
 Hg mercury
 hhd hogshead, 53
 hks hektostere, 54
 hl hectoliter, 50
 hp horse-power, 81
 hp-h horse-power hour, 77
 hp-m horse-power-minute, 76
 hp-s horse-power-second, 75
 I, i, *I*, *i* current, (elec.) intensity of, 22, 112
 I, *I* intensity of light, 16, 144
 I intensity of magnetization, 142
 in inch, 30
 in² square inch, 42
 in³ cubic inch, 47
 in Hg inch of mercury column, 65
 in/m inch per mile, 90
 int. international
 J, j joule, 15, 74, 123, 143
 J mechanical equivalent of heat, 26
 k electric inductive capacity, 14, 18, 23, 24
 k dielectric constant, 23
 K moment of inertia, 19
 kg kilogram, 58
 kg cal kilogram calorie, 171
 kg-C kilogram Centigrade heat unit, 76
 kg-km kilogram-kilometer, 76
 kg-km/min kilogram-kilometer per minute, 81
 kg-m kilogram-meter, 75
 kg-m/min kilogram-meter per minute, 80
 kg-m/s kilogram-meter per second, 81
 kg/cm² kilogram per square centimeter, 66
 kg/cm³ kilogram per cubic centimeter, 69
 kg/day kilogram per day, 127
 kg/h kilogram per hour, 127
 kg/hl kilogram per hectoliter, 68
 kg/km kilogram per kilometer, 62
 kg/l kilogram per liter, 69
 kg/m kilogram per meter, 63
 kg/m² kilogram per square meter, 64
 kg/m³ kilogram per cubic meter, 68
 kg/mm² kilogram per square millimeter, 66
 kg/t kilogram per ton (metric), 78
 kg/yr kilogram per year, 126
 kl kiloliter, 54
 km kilometer, 30
 km² square kilometer, 43
 kw-h kilowatt-hour, 77
 km/hr kilometer per hour, 85
 km/hr/min kilometer per hour per minute, 88
 km/hr/s kilometer per hour per second, 88
 km/min kilogram-meter per minute, 86
 kw kilowatt, 82
 kw-m kilowatt-minute, 76
 kw-s kilowatt-second, 75
 L, l, *L*, *l* inductance, self-induction, 23, 118
 L, *l* length, 18
 l liter, 48
 lb pound, 58
 lb-C pound Centigrade heat unit, 75
 lb-C/min pound-Centigrade heat unit per minute, 81
 lb-F pound-Fahrenheit heat unit, 75
 lb-F/min do. per minute, 81
 lb/bu pound per bushel, 68
 lb/day pound per day, 127
 lb/ft pound per foot, 63
 lb/ft² pound per square foot, 64
 lb/ft³ pound per cubic foot, 68
 lb/gal pound per gallon, 68
 lb/h pound per hour, 127
 lb/in pound per inch, 63
 lb/in² pound per square inch, 65
 lb/in³ pound per cubic inch, 69
 lb/ml pound per mile, 62
 lb/qt pound per qt, 63
 lb/tn pound per ton (av), 78
 lb/yd pound per yard, 62
 lb/yd³ pound per cubic yard, 68

lb/yr pound per year, 126
 li link, 31
 log logarithm, 171
 $\log_{10}$ common logarithm, 171
 $\log_e$ Napierian logarithm, 171
 m magnet pole, strength, 20
 M mass, 18
 M mechanical equivalent of heat, 171
 m meter, 30
 m minute, duration, 94
 ^{m} minute, time of day, 93
 m^2 square meter, 43
 m^3 cubic meter, 50
 $m/\min$ meter per minute, 85
 m/s meter per second, 85
 $m/\sec^2$ meter per second per second, 88
 mg milligram, 57
 mg/mm milligram per millimeter, 62
 mg/s milligram per second, 127
 mil^2 square mil, 41
 $\min$ minute, 94
 ml milliliter, 46
 ml mile, 31
 ml^2 square mile, 43
 $ml\text{-}lb$ mile-pound, 76
 $ml\text{-}lb/\min$ mil-pound per minute, 81
 ml/hr mile per hour, 85
 $ml/hr/\min$ mile per hour per minute, 88
 $ml/hr/\sec$ mile per hour per second, 88
 $ml/\min$ mile per minute, 86
 mm millimeter, 30
 mm^2 square millimeter, 41
 mm^3 cubic millimeter, 52
 $mm\text{ Hg}$ millimeter of mercury column, 65
 mm/m millimeter per meter, 90
 $m.m.f.$ magnetomotive force, 132
 mo month, 94
 mol gram molecule, 60
 N number of turns, 20
 n, n any number
 n frequency, 23, 87, 121
 na nail, 31
 O ohm, 15
 O oxygen, 126
 oz ounce, 58
 oz/h ounce per hour, 127
 $oz/\min$ ounce per minute, 127
 p page
 p pole (length), perch, 32
 p pressure, 19
 P, P power, activity (mechanical, electric, magnetic, etc.), 19, 20, 23, 124, 144
 $p.d.$ difference of potential, 108
 "per" between two units means first divided by second, 4
 $phys.$ physical or physics
 pk peck, 49
 pt pint, 47
 Q, q, Q, q quantity of electricity, 22, 115

Q, Q quantity of light, 16, 149
 qr quarter, 31, 53, 60
 qt quart, 48
 R, r, R, r resistance (electric), 22, 97
 R Réaumur degrees, 150
 R reluctance, 129
 R rood, 44
 r rod, 32
 rev revolution, 89
 rev/h revolution per hour, 86
 $rev/\min$ revolution per minute, 86
 $rev/\min/\min$ revolution per minute per minute, 88
 $rev/\min/s$ revolution per minute per second, 88
 rev/s revolution per second, 86
 $rev/s/s$ revolution per second per second, 88
 rhp revolution per hour, 86
 rpm revolution per minute, 86
 rps revolution per second, 86
 s second, duration, 94
 ^{s} second, time of day, 93
 s shilling, 165
 s stere, 51
 S, s surface, 18
 $\sec$ second
 sp specific
 $sp. gr.$ specific gravity, 18
 sq square, 41
 $S.U.$ Siemens unit, 99
 $subtr.$ subtract
 T, t time, 18
 t temperature degrees, 111
 t ton, metric, 58
 $t\text{-}km$ ton-kilometer, 78
 t/cm^2 ton (metric) per square centimeter, 67
 t/m^2 ton (metric) per square meter, 65
 t/m^3 ton (metric) per cubic meter, 69
 t/yr ton (metric) per year, 127
 tn ton (avoirdupois), 58
 $tn\text{-}ml$ ton-mile, 78
 tn/ft^2 ton (av) per square foot, 66
 tn/in^2 ton (av) per square inch, 66
 tn/yd^3 ton (av) per cubic yard, 69
 tn/yr ton (av) per year, 127
 U, u, U, u difference of potential, 22, 108
 $U.S.$ United States
 v velocity, 19
 v, v velocity of light, 14, 21, 24, 96
 V, V volume, 18, 69
 V, v volt, 15, 110
 $vol.$ volume
 W, w watt, 15, 80, 125
 W weights, 69
 W, W work, energy (mechanical, electric, magnetic, etc.), vis-viva, impact, 19, 20, 23, 122, 143
 $w\text{-}h$ watt-hour, 76
 $w\text{-}s$ watt-second, 74
 X, x, X, x reactance, 22, 97
 x_c capacity reactance, 22

x_m magnetic reactance, 22
 Y, y, Y, y admittance, 22, 104
 yd yard, 30
 yd^2 square yard, 42
 yd^3 cubic yard, 50
 yr year, 94
 Z, z, Z, z impedance, 22, 97

α (alpha) angle, 18
 β (beta) angle, 18
 γ (gamma) conductivity (electric), 22, 105
 γ 0.001 milligram, 59
 δ (delta) density, 18
 θ (theta) temperature, 13, 18, 26
 κ (kappa) susceptibility, 20, 132
 μ (mu) magnetic permeability, 14, 18, 20, 131
 μ micron or micro-meter, 31
 $m\mu$ milli-micron, 31
 ν (nu) reluctivity, 20, 130
 π (pi) angle of 180° , 89
 π ratio of circumference to diameter, 169
 ρ (rho) resistivity, 22, 101
 ϕ (phi) angle of phase difference, 124
 Φ, ϕ (phi) magnetic flux, 20, 137
 Φ flux of light, 16, 147
 ω (omega) angular velocity, 19, 23, 86, 121
 $\mathcal{B}$ flux density, magnetic induction, 20, 140
 $\mathcal{C}$ magnetic capacity, 20

$\mathcal{F}$ magnetomotive force, 20, 132
 $\mathcal{H}$ magnetizing force, field intensity, 20, 134
 $\mathcal{H}$ flux density, 140
 $\mathcal{I}$ intensity of magnetization, 20, 142
 $\mathcal{M}$ magnetic moment, 20, 142
 $\mathcal{R}$ reluctance, 20, 129
 $\times$ multiplication
 - (hyphen) between two units means their product, 4
 + division, first quantity divided by the second
 $\%$ per cent or per hundred, 7, 90
 $\frac{1}{100}$ per mil or per thousand, 8, 90
 $\sqrt{\quad}$ square root
 $\sqrt[3]{\quad}$ cube root
 $\frac{1}{\quad}$ reciprocal
 2 square, 41
 $\frac{1}{2}$ square root
 $\frac{1}{3}$ cube or cubic, 46
 $\frac{1}{4}$ cube root
 10^n for condensed numbers, 8
 $^\circ$ degree, 89
 $'$ foot
 $'$ minute, 89
 $''$ inch
 $'''$ second, 89
 $'''$ line ($1/12$ inch)
 $\pounds$ pound sterling, 165
 $\$$ dollar in the United States, 166
 $\mathfrak{z}$ dram, apothecary, 59
 $\mathfrak{z}$ ounce, apothecary, 59
 $\mathfrak{z}$ scruple, 59
 $\mathfrak{z}$ frequency, 87, 121

INTRODUCTION.

INTER-RELATION OF UNITS.

In order to establish a stable, systematic set of relations between the various units in use, the first requisite is to find which the proper fundamental relations are, otherwise the secondary relations may have different values depending upon how they have been calculated, that is, they will form an unstable system. Such simple relations as those between pounds, ounces, grams, kilograms etc., are definitely established by law and are well known. The relations between units of length and units of capacity (volume) are slightly less simple but are also, or at least should be, established by law. The relation between what are commonly called weights (more correctly masses) and lengths, becomes somewhat more complicated, but by means of the mass of water these two kinds of units become definitely connected with each other, at least in the metric system, and from that to all others; this relation is also defined by law.

But with the more widely differing units the relations become more complicated. It may even seem at first thought as though there was no relation between such units as a foot and a horse-power or a watt; or between a pound and a degree of a thermometer, or between a foot and an ampere of electric current, etc. Yet all such units can be shown to be connected with each other, often more simply than might at first appear. In a set of values of different units in terms of the others it is therefore necessary to find and establish all the necessary fundamental relations, and no more, or else the system is not a stable one, and the derived values become different, depending upon how they are calculated.

To find the connecting links between such widely different units, it is necessary to reduce them to some unit or quantity common to all, as a direct numerical equivalent can be given only between units of the same kind. This common unit, or quantity, and the only one, is energy. Energy can be expressed in terms of combinations of all the different units commonly used in practice, and by expressing the same amount of energy in terms of these different combinations of units their relations to each other may be established.

An analysis shows that there are three typically different sets of well-established units in common use, in terms of which energy is expressed or measured, and these three sets or groups include all the units generally used.

The first and most stable or fundamental are the absolute units and all those having a known and invariable relation to them; these include the electrical units, which are the newest, and were wisely based on the absolute ones. They are the same throughout the universe; they are invariable and are independent of any constant of nature, except perhaps the unit of time, which depends on the revolution of the earth around the sun, but as this has been so accurately determined it may safely be considered here as an absolute quantity; it is at least invariable throughout the universe.

The next group of units is the one involving the constant of nature called the attraction of gravitation of our earth, and they are therefore often called gravitation units; they are, therefore, purely terrestrial units, and would be quite different on other celestial bodies, and, in fact, are, strictly speaking, different even on different parts of this earth, although for most purposes they may be considered to be the same. They include such units as the pound or kilogram considered as weights, the horse-

power as usually defined, etc. It will be found upon investigation that this whole group is linked with the first group, namely, the absolute and electrical units, through the value of the acceleration of gravity, a terrestrial constant of nature, and unfortunately one which is variable and has no universally accepted normal value. If some standard normal value of this constant were universally established and were fixed definitely, this group of units would be connected with the absolute units by a fixed relation, and the former would then all have definite and invariable values in terms of the absolute units. The acceleration of gravity is therefore the connecting link, and the only one, between these two groups. Throughout the tables in this book the standard value of the acceleration of gravity has been taken as 980.596 6 cm (the authority is given under units of Acceleration).

The third and last group of units is the one involving a property of water, which is also a constant of nature. This group includes such units as the calorie, the thermal unit, the degrees of thermometer scales, etc. It will be found upon investigation that this whole group of units is linked with the first group, namely, the absolute and electrical units, through the value of the specific heat of water; and moreover this is the only connecting link. This constant differs from the acceleration of gravity, which is the connecting link between the first and second groups, in that it has not a variable value like gravity; but, on the other hand, its value has not yet been determined with such accuracy. It is like gravity in that it is a constant of nature whose value must be determined by experiment and definitely established before fixed and stable relations between this group of units and the absolute units can be established.

The relations between the various units in any one group are, as a rule, fixed by definition or by law; the horse-power, for instance, is defined in terms of the foot-pound and the minute; or the calorie is defined in terms of the thermometer scale and a quantity of water. Such relations are therefore established and require no experimentally determined constant in order to express their relations to each other; no matter what the value of the specific heat of water is, the relation between the calorie and the thermometer scale is fixed. But when we wish to express the values of any of the units of one group in terms of units of the other, then the numerical values of these two connecting links, namely, the acceleration of gravity and the specific heat of water, must be known. If, for instance, horse-powers are to be expressed in absolute or electrical units like watts, the value of gravity must be known; or if calories are to be expressed in absolute or electrical units like joules, the value of the specific heat of water must be known; or if calories are to be expressed in foot-pounds, then both these constants of nature must be known.

Moreover, the values of gravity and the specific heat of water are the only two constants that must be known in order to reduce any of these different units of energy to any of the others. By accepting or fixing a definite value for each of these two constants the relations between all the units of these three groups become linked together into one single stable system in which all the relations between any of the units remain absolutely the same no matter how they have been calculated. As no standard values of either of these two constants have as yet been universally accepted or agreed upon, which is very unfortunate, the writer has, in the preparation of these tables, selected certain values as the ones which seem to be the best that exist at the present time, and which at least have a semi-official endorsement.

As the establishment of fixed values for these two constants forms an inflexible stable system of units, there must exist some relation between these two constants themselves. It can readily be shown that the specific heat of water divided by the acceleration of gravity gives the mechanical equivalent of heat, when all are reduced to the same terms. The value used throughout this book is 426.9 kilogram-meters per kilogram-Centigrade heat unit (see authority under units of Energy). When thus defined this constant becomes a secondary or derived one,† which is as it should be,

† While this is, strictly speaking, the more rational way of deducing those constants, yet the author has preferred to accept the simpler value above given for the mechanical equivalent and has made the specific heat the incommensurable derived unit for reasons explained under units of Energy.

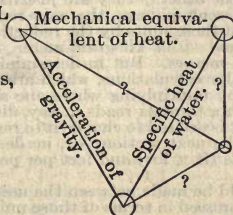
because it does not involve the absolute units, but is the relation between the second and third groups, both of which are separated from the absolute units by one of these two empirical and therefore less stable constants.

If the heat units and what are called the gravitational units, like the pound (weight), the horse-power, etc., had originally been defined in terms of the absolute units, as was wisely done with the electrical units, there would have been no necessity of knowing the values of gravity, the specific heat of water, or the mechanical equivalent of heat, in order to establish fixed and invariable relations between all the units in use. Such fixed relations would then be established definitely by definition. Concrete standards of measurement complying as closely as possible with the defined values would then require the experimental determinations of these constants, but the exact theoretical relations would not. Such is the case with the electrical units which are defined with absolute accuracy in terms of the absolute units and require no experimentally determined constant to connect them with the absolute units; in the electrical system of units the problem therefore is not to find such an empirical relation, but to determine concrete standards which comply with the defined relations as closely as possible.

If those on whom the duty will fall to establish a system of units of light would follow the good example set by those who established the electrical units, and base them on the absolute system of units, instead of on another different constant of nature, like the candle or incandescent platinum, they would avoid creating a fourth group of units whose empirical relation to the absolute, electrical, and to the other two groups of units would have to be determined, and would be uncertain until it was. What is called radiated light, usually measured in spherical candle-power, is a true power or a rate of work, and the absolute unit would therefore be a dyne-centimeter per second. If the practical unit could be defined as a decimal multiple or fraction of this, like the watt is, it would at once become a definitely known unit. It would then become necessary, as it was with the three fundamental electrical units, to establish a concrete standard which would comply as definitely as possible with the defined unit. If, however, the practical unit is defined on some independent basis, like the present unsatisfactory and uncertain temporary light units, it will become necessary to determine experimentally the mechanical equivalent of light, before any of the much-needed relations could be established with the other existing units, like the electrical, gravitational, or heat units. In the case of light units the matter becomes complicated on account of the different wave-lengths and combinations of wave-lengths which have different effects on the eye in perceiving light. Owing to the absence of any known relations between light energy and energy stated in other units, no relations between those groups of units could be given in this book.

The relations above described, which exist between the different groups of units, may be represented graphically as shown in the following diagram:

GRAVITATIONAL UNITS and their derivatives; gram or pound as weights, foot-pounds, horse-powers, etc.



HEAT UNITS and their derivatives; calorie, thermal unit, thermometer scale, etc.

LIGHT UNITS and their derivatives; candle power, lux, etc.

ABSOLUTE or ELECTRICAL UNITS and their derivatives; gram or pound as masses, dyne, centimeter, foot, second, watts, joules, etc.

The most fundamental, namely, the absolute or electrical units, are shown at the bottom. The gravitational units to the left are shown linked to these through the value of the acceleration of gravity. The heat units to the right are shown linked to the absolute and electrical units through the value of the specific heat of water. Finally, the gravitational units are linked to the heat units through the mechanical equivalent of heat, which is the quotient of the other two linking values. The relation of any one of the three to either one of the others can be found either by means of the direct link or indirectly by means of the two other links; the result must be the same if the values expressed by these links are definitely established.

The group of units of light at present in temporary use are shown as a fourth group, the connecting links of which are unfortunately not yet known, for which reason no relations to other units can be given, although such definite relations it seems ought of necessity to exist at least when light is considered as a radiation of some definite wave-length.

COMPOUND NAMES OF UNITS.

When in compound names of units of measurement the names of the simple units are *joined by a hyphen*, as in foot-pounds, horsepower-hours, etc., it signifies the *product* of the simple units; that is, an amount of energy stated in foot-pounds means that the number of feet is multiplied by the number of pounds, to give the foot-pounds; in other words, the compound quantity varies directly with each of the others. If, however, the simple units are *joined by the word "per"* as in feet per second, pounds per mile, etc., it means that the first is *divided* by the second; that is, a velocity in feet per second means that the number of feet is divided by the number of seconds. In other words, the compound quantity varies directly with the first and inversely with the second. An acceleration in "miles per second per second" means that the velocity in miles per second is divided by the number of seconds during which this velocity was acquired.

The above is the correct practice, but it is unfortunately not followed by all writers. For instance, "horsepower per hour" is wrong; it should be horsepower-hour, as the number of hours is a multiplier and not a divisor.

DISTINCTION BETWEEN UNITS AND QUANTITIES MEASURED IN THOSE UNITS.

Serious errors are not infrequently made by failing to distinguish between the calculations of the values of the units themselves and the calculation of quantities measured in terms of those units. By using the reduction factors in the way they are given in the tables in this book, no mistakes can be made as the units have all been calculated, and the value of each unit is given in terms of each of the others; they are just like the selling prices of one apple in terms of different moneys, the only remaining calculation is to multiply the quantity of these units by the reduction factor given in the table; thus, if 1 foot-pound = 0.14 kilogram-meter, then 3 of these foot-pounds = 3×0.14 kilogram-meters. But in determining the reduction factors themselves, or in similar calculations, which are not infrequent, errors are very apt to be made by multiplying where one should divide. A frequent case is that in which a formula reads in, say, distances in meters and weights in kilograms and it is desired to change it to read in feet and pounds; this will be described in the next section; or, in dealing with compound units, such as foot-pounds ($\text{ft} \times \text{lbs}$) and feet per pound ($\text{ft} \div \text{lbs}$), which were described above.

A clear distinction should be made between the units themselves and the quantities measured or expressed in terms of those units. Thus, 1 foot = 12 inches is the value of one unit in terms of another, but it is not correct to interpret this by saying: a length in feet = $12 \times$ its length in inches, as that would be 144 times too great. It should be interpreted as follows: If 1 foot equals 12 inches, then a length of any other number of *feet* must be multiplied by 12 to reduce that length to *inches*, or to express it in terms of inches. Simple as this may seem in this almost self-evident illustration, mistakes are easily and frequently made in more obscure relations, especially

in substituting one kind of a unit for another in a formula, which will be described in the next section.

The larger the unit the smaller will be the number of those units which are contained in a given quantity; that is, the smaller will be the number expressing the size of that quantity in terms of those units. For instance, a meter is *greater* than a yard, hence the number of meters in a given distance is *less* than the number of yards. This self-evident rule is often of value as a check to avoid confusion between the calculation of the units themselves and the quantities in terms of those units; errors of this kind are especially liable to occur when the two units have nearly the same values.

This rule should not be confounded with another quite different case in which the values of two different units are given in terms of the same third unit; for instance, 1 kilogram-meter = 2.3 heat units and 1 foot-pound = 0.32 of the same heat units; here the foot-pound is a smaller unit than the kilogram-meter, hence its value in terms of a third unit will of course also be smaller. But 1 heat unit = 3.1 foot-pounds and 1 heat unit = 0.43 kilogram-meter; here the same quantity, 1 heat unit, is expressed first in small units, namely, foot-pounds, then in large units, kilogram-meters; hence 3.1, the number of the smaller units, is of course greater than 0.43, which is the number of the larger units.

In calculating one unit from another unit, great care must be taken to avoid multiplying when one should divide, or the reverse. Thus if the unit 1 kilogram-meter equals 2.3 heat units, it would not be correct to say that because the unit 1 kilogram = 2.2 lbs and 1 meter = 3.3 feet, therefore the unit 1 foot-pound = $2.3 \times (2.2 \times 3.3) = 16.8$ of those heat units; it should be $1 \text{ foot-pound} = 2.3 \div (2.2 \times 3.3) = 0.31$ heat units. The safest way to avoid such errors is to remember that the statement 1 kilogram-meter = 2.3 heat units really is a true equation between units and means $1 \text{ kilogram} \times 1 \text{ meter} = 2.3 \text{ heat units}$; one should then substitute for 1 kilogram its equal in terms of the other unit, namely 2.2×1 pound, and for 1 meter its equal, namely 3.3×1 foot; then $2.2 \times 1 \text{ pound} \times 3.3 \times 1 \text{ foot} = 2.3 \text{ heat units}$, which when reduced gives the unit $1 \text{ foot-pound} = 2.3 \div (2.2 \times 3.3)$ or 0.31 heat unit. These terms here always refer to units and not to quantities measured in terms of those units, which latter is the case in formulas.

Expressing this relation in algebraical terms, it means $A \times B = 2.3C$, in which A is one kilogram and not a weight denoted in kilograms, B is one meter and not a distance expressed in meters, and C is one heat unit; they should here be considered as concrete things like a certain piece of brass, a certain stick, and a certain lump of coal, as distinguished from abstract units or as distinguished from a mere number representing a measurement in terms of those units. Now if in the same way a is one pound or a different piece of brass, and b is one foot or a different stick, then as $1 \text{ kilogram} = 2.2$ pounds, it follows that $A = 2.2a$ and similarly $B = 3.3b$. Substituting these in the first equation gives $2.2a \times 3.3b = 2.3C$, which when reduced gives $a \times b = 2.3 \div (2.2 \times 3.3)C = 0.31C$.

In formulas, however, the letters do not stand for the *units* themselves, but for *quantities measured in terms of the units*, and hence one must multiply instead of divide, or the reverse, as will be explained in the next section.

A similar error is very apt to arise in calculating units containing the word "*per*," which word signifies a division, as was explained above under compound units. This is the case, for instance, in finding the value of 1 kilogram per kilometer from the value of 1 pound per foot, or a velocity of 1 mile per minute from that of 1 foot per second. It must be remembered that the unit following the word "*per*" is a divisor. The safest way always is, as above described, to write out the whole expression carefully, then substitute equivalent values and reduce. Thus: 1 mile per minute = 26.8 meters per second, may be written $1 \text{ mile} \div 1 \text{ minute} = 26.8 \text{ meters per second}$; then to find the value of 1 foot per second from it, substitute 5 280 feet for 1 mile, and 60 seconds for 1 minute, thus $(5\,280 \times 1 \text{ foot}) \div (60 \times 1 \text{ second}) = 26.8 \text{ meters per second}$; then reduce by dividing both sides by 5 280 and multiplying both by 60, giving $1 \text{ foot} \div 1 \text{ second}$, or 1 foot per second = $26.8 \div 5\,280 \times 60 = 0.30$ meter per second.

When the unit following the word "*per*" is not to be changed, then the division just referred to does not enter into the calculation. Thus to reduce some value of 1 foot per *minute* to that of 1 mile per *minute* or to that of 1 meter per *minute*, is merely a reduction of feet to miles, or to meters.

REDUCING FORMULAS FROM ONE KIND OF UNITS TO ANOTHER.

It often occurs in practice that a formula is given for one set of units, such as meters, kilograms, seconds, etc., and it is desired to use it for other units such as feet, pounds, minutes, etc. While this is generally a simple calculation, it is very apt to be made incorrectly, giving an entirely wrong result. The error arises from the fact that one is apt to forget the distinction between a unit and a quantity measured in terms of that unit (see the preceding section) which distinction involves the difference between whether one should multiply or divide. For instance, a foot is *larger* than an inch, but the *number of feet* expressing a certain distance is *smaller* than the *number of inches* expressing that same distance.

The best way to avoid mistakes is to remember that *in the usual formulas the letters represent quantities measured in terms of certain units*; they do not represent the units themselves. To change a formula from one kind of units to another, it is therefore necessary to replace each letter of the original formula by another letter combined with such a reduction factor as will reduce the measurement made in terms of the new unit, to that made in terms of the original one. Thus if a formula contains the letter L as representing length expressed in meters, and it is desired to change this to l expressed in feet, then substitute for L the equivalent $l \div 3.28$ or $l \times 0.305$, because any length l measured in feet when divided by 3.28 (or multiplied by 0.305) will be that same length expressed in meters; and as the original formula is correct for meters, it will be correct to substitute $l \times 0.305$ for L because the number thus obtained will be the same as the number which expresses L in meters. Or, if the original formula contains the letter W , representing weight expressed in kilograms, and it is desired to change it to w expressed in pounds, then substitute for W the equivalent $w \times 0.454$, because any weight in pounds when multiplied by 0.454 will give the same number as when expressed in kilograms, which latter number is what the original formula called for. After having thus replaced each letter by a new one and a constant, all these constants may be combined into one if desired.

It must not be forgotten that the quantity which the whole formula represents, that is, the quantity which is to be calculated by means of the formula, is generally also in terms of some unit (unless it is a mere ratio, percentage, or number), and care must therefore be taken to also substitute a new letter and reduction factor for it, if it is desired to change it also. For instance, if a formula for determining the metric horse-power from data given in meters and kilograms, is to be changed to read in feet and pounds, as just described, the value obtained in applying the new formula would still be in metric horse-power, notwithstanding that the formula has been reduced to feet and pounds; if the result is to be in English horse-powers, then the letter representing the metric horse-power must likewise be changed to a new one with its reduction factor, just as was done with the others. This will be illustrated below by an example.

The safest rule of thumb for the changing of the units of a formula is therefore as follows: *Substitute for each letter of the old formula a new letter multiplied by the value of the NEW unit in terms of the OLD one*, as given in the tables in this book. Then the new letters will represent quantities measured in terms of the new units. Thus for L (meaning meters) substitute l (meaning feet) $\times 0.305$, this number being the value of one foot (new unit) in terms of meters (old unit), as obtained from the tables. For if 1 foot = 0.305 meters, any other number of feet (namely l) must be multiplied by 0.305 to reduce it to the number of meters (L) called for by the original formula; or, in other words, L and $l \times 0.305$ are equivalents, and either may be substituted for the other.

Or put into algebraical terms: if according to the table 1 foot = 0.305 meter, then l feet are equal to $l \times 0.305$ meters; or a length represented by l in feet is represented by $l \times 0.305$ in meters; but the latter quantity is numerically equal to L , hence $L = l \times 0.305$, which is a true equation in which the letters represent the same length measured first in meters and then in feet; and $(l \times 0.305)$ may therefore be substituted for L in any formula.

The above rules are illustrated in the following example: Let

$$P = 16 \frac{WL}{T},$$

in which P represents the power in metric horse-power which is required to operate a windlass or elevator to raise W metric tons L meters in height in T seconds. The constant 16 includes the friction loss, and the reduction factors. It is required to change this to English horse-powers (p), short tons (w), feet (l), and minutes (t).

From the tables, one English horse-power (the new unit) is equal to 1.01 metric horse-powers (the old unit), hence $P = p \times 1.01$. One short ton of 2 000 lbs. is equal to 0.907 metric ton, hence $W = w \times 0.907$. One foot equals 0.305 meter, hence $L = l \times 0.305$, and one minute equals 60 seconds, hence $T = t \times 60$. The constant 16 being in terms of no unit, as it is a mere number or ratio, remains unchanged. Substituting all these in the old formula, gives

$$p \times 1.01 = 16 \frac{w \times 0.907 \times l \times 0.305}{t \times 60},$$

which when all the constants are combined, gives the new formula

$$p = 0.073 \frac{wl}{t},$$

which will be correct for quantities expressed in terms of the new units.

When the original formula is to be applied only once for one set of values in other units, it may sometimes be simpler to reduce the original data in short tons, feet, and minutes to metric tons, meters, and seconds by means of the tables; then substitute them in the original formula and calculate the result, which will be in metric horse-power; then reduce this result back to English horse-power by means of the tables.

RATIOS.

A ratio means the relation of one quantity to another, that is, one quantity divided by the other. It is therefore always a mere number and is independent of any units, except that the two quantities concerned must always be in terms of the same units. When the statement is made that a certain number is the ratio of one quantity to another, it invariably means that the *first* was divided by the *second*, and never the reverse. A convenient rule of thumb for calculating the ratio is to *divide by the one that is preceded by the word "to."*

Unless otherwise stated, a ratio is the figure thus obtained by division and when it is reduced to a single number (as distinguished from a vulgar fraction) it means so-and-so much per unity. Thus a ratio may be expressed as 3 to 4 (or $\frac{3}{4}$) for instance, or as 0.75; in the latter case it means 0.75 per unity. Ratios are, however, more frequently stated as percentages, that is, as ratios per 100, in which case the above defined value must be multiplied by 100. Thus the ratio of 3 to 4 is then expressed as 75%, as described more fully below.

PERCENTAGE.

Percentage values represented by the sign % and meaning *per hundred*, are often used as a convenient way of representing a ratio, fraction, or relation, so as to avoid the use of fractions, at least in most cases. Thus a recovery of 3 horse-power out of 4 may be expressed as the fraction $\frac{3}{4}$ or 0.75, or it may more conveniently be expressed as 75%, which avoids fractions and reduces the relation to one which is based on 100. The objection to it is that such values of necessity introduce a multiplication or division by 100, which sometimes gives rise to confusion. To have adopted the system of stating such values *per unity* instead of *per hundred*, would have avoided this confusion, but the values would then in most cases be fractions, for which reason the percentage values are usually preferred.

Percentage values, like other ratios, are mere numbers and are not in terms of any units; they are moreover the same for all units provided only that the two quantities from which the percentage value is calculated are always in terms of the same units.

While percentages occurring in practice are generally between 1 and 100, yet they may of course be less than 1 or greater than 100. When less than 1 care should be taken to write and read them properly; thus .25%, for instance, which means $\frac{1}{4}$ of 1%, is often incorrectly read as 25%. A safe way to write it in such a case is to say " $\frac{1}{4}$ of 1%," or "25 hundredths of a percent." Six percent interest, for instance, should always be written 6%, or 0.06, but never 0.06%.

When a given percentage value is to be applied, it is almost always the case that some quantity measured in units is to be multiplied by it. In that case it becomes very important to divide either the percentage value or the product by 100, in order to get the actual value in those units. Thus 25% of 8 is $0.25 \times 8 = 2$ or $(25 \times 8) \div 100 = 2$. Frequent and serious errors arise by neglecting this, and in carelessly retaining the percent sign (%) after dividing by 100, by writing for instance 0.06% for 6%.

When the percentage value is to be found from two given quantities, errors are frequently made by dividing by the wrong quantity. Percentage values are usually expressed by saying that one quantity is a certain percent of another, and this means that the *first* must be divided by the *second*, and then multiplied by 100. A good rule of thumb is to *divide by the one preceded by the word "of,"* and then multiply by 100. Thus, 2 is what percent of 8; here 2 is to be divided by 8 and multiplied by 100, giving 25%.

Care should also be taken to reduce the original figures to their proper form before dividing them to find the percentage. Thus to find what percent is 6 less than 8, reduce it to the form "what percent is 2 (that is, 8 minus 6) of 8"; then divide 2 by 8 and multiply by 100, giving 25%. Or, what percent is 8 greater than 6; divide the difference 2 by 6 and multiply by 100, giving $33\frac{1}{3}\%$.

The sign ‰ is sometimes used, more particularly abroad, in stating grades. This differs from percent only in that it means per 1 000 instead of per 100.

CONDENSED NUMBERS. The Use of 10^n .

For convenience, brevity, and clearness the decimal point in very large or very small numbers is often moved to the next to the last left-hand digit, and the amount by which it has thereby been lowered or raised is written separately in the form of 10 to the required power. Thus the large number 1 230 000 is often written 1.23×10^6 (that is, $1.23 \times 1\,000\,000$); or 0.000 001 23 is written 1.23×10^{-6} (that is, $1.23 \times 0.000\,001$). A positive exponent of 10 indicates that the real number is larger than the one given, and a negative exponent, that it is smaller. The *exponent*, whether positive or negative, always indicates the *number of places* that the decimal point has been moved. When the exponent is negative it also means that in the original number there is one less zero between the point and the first digit than the exponent indicates; thus 10^{-6} means that there are 5 zeros between the point and the first figure; this, however, applies only when the decimal point in the condensed number is between the first and second left-hand digits, as usual; sometimes, though not according to good practice, 1.23×10^{-6} is written 12.3×10^{-7} , in which case this rule of thumb does not apply.

To multiply or divide such condensed numbers, perform that operation with the numerical part, and then merely add (algebraically) the exponents of the 10's in the case of a multiplication or subtract them (algebraically) in the case of a division. Thus $(3.4 \times 10^5) \times (5.6 \times 10^4) = 19.04 \times 10^{10}$ or better, 1.904×10^{11} . Or $(3.4 \times 10^{-6}) \times (5.6 \times 10^{-4}) = 19.04 \times 10^{-10}$, or better 1.904×10^{-9} . Again, $(1.2 \times 10^6) \div (3.4 \times 10^{-4}) = 4.08 \times 10^{10}$; or $(4.08 \times 10^2) \div (3.4 \times 10^{-4}) = 1.2 \times 10^6$, as -4 subtracted from $+2$ gives $+6$.

To square, cube, etc., such a condensed number, perform that operation with the numerical part and multiply the exponent of 10 by 2, 3, etc., respectively. For extracting the square or cube root, perform that operation with the numerical part and divide the exponent of 10 by 2, 3, etc., respectively; if this does not divide evenly, then first change the exponent so that it will, by moving the decimal point in the numerical part; thus, to extract the cube root of 6.4×10^7 , write it $64. \times 10^6$, then the cube root is $4. \times 10^2$.

To add or subtract such condensed numbers they must first be reduced to the same power of 10; then add or subtract the numerical parts and affix 10 to the same power. Thus $(1.23 \times 10^4) + (4.56 \times 10^3) = (12.3 \times 10^3) +$

$(4.56 \times 10^3) = 16.86 \times 10^2$, or better, 1.686×10^3 . The same rule applies when all the exponents are negative, or when some are positive and some negative, although in the latter case it will generally be simpler to reduce all to the real numbers by eliminating the factor 10.

10^0 is never used in such numbers, but it sometimes results from calculations. It is equal to 1, and is therefore always omitted.

TABLE OF CONDENSED NUMBERS.

Let 1.23 represent any number, of any number of places of figures; then:

1.23×10^6	=	1 230 000.
1.23×10^5	=	123 000.
1.23×10^4	=	12 300.
1.23×10^3	=	1 230.
1.23×10^2	=	123.
1.23×10^1	=	12.3
1.23×10^0	=	1.23
1.23×10^{-1}	=	0.123
1.23×10^{-2}	=	0.012 3
1.23×10^{-3}	=	0.001 23
1.23×10^{-4}	=	0.000 123
1.23×10^{-5}	=	0.000 012 3
1.23×10^{-6}	=	0.000 001 23

PREFIXES used in the METRIC SYSTEM.

Micro-	0.000 001	or	10^{-6}
Milli-	0.001	or	10^{-3}
Centi-	0.01	or	10^{-2}
Deci-	0.1	or	10^{-1}
Deca- or Deka-	10.	or	10^1
Hecto- or Hekto-	100.	or	10^2
Kilo-	1 000.	or	10^3
Myria-	10 000.	or	10^4
Mega-	1 000 000.	or	10^6

Thus one *millimeter* equals 0.001 meter, or one *kilometer* equals 1 000 meters.

ACCURACY OF APPROXIMATE OR ABBREVIATED NUMBERS.

When a value is known to be correct only to a limited number of places of figures, or when the figures are abbreviated to a few places, the possible error in such approximate figures, or in other words their accuracy, varies not only with the number of places of figures, but also with the value of the left-hand digit, as will be explained below. It is here assumed that the last right-hand figure has always been increased by one, when the next figure would be 5 or over; thus anything between 12.85 and 12.89 (including the former) would be abbreviated to 12.9, while anything between 12.80 and 12.85 (but not including the latter) would be abbreviated to 12.8.

The possible error is *less* the *greater* the number of places of figures. For two places of figures (from 10 to 99) the greatest error (namely ± 5 in the 3d place) is from 5% for the smaller numbers to $\frac{1}{2}\%$ for the larger. For three places of figures (100 to 999) the greatest errors are $\frac{1}{2}\%$ to $\frac{1}{20}\%$. For four places of figures, the greatest errors are $\frac{1}{20}\%$ to $\frac{1}{200}\%$. For five places $\frac{1}{200}\%$ to $\frac{1}{2000}\%$, etc.

The possible error is also *less* as the left-hand digit is *greater*. Thus the abbreviated number 10.1 may mean anything from 10.05 to nearly 10.15, and the greatest error may therefore be ± 5 in the next (2d) place of decimals, or numerically this would be 5 times the left-hand digit 1. But in the abbreviated number 99.9, which may mean anything from 99.85 to nearly 99.95, the greatest error, namely ± 5 , is only about $\frac{5}{10}$ times the left-hand digit 9; that is, in percentage only about $\frac{1}{10}$ as great an error as it was for 10.1. It follows therefore that values beginning (at the left hand) with the low digits 1, 2, 3, etc., should be stated to one place more than those beginning with the high digits 9, 8, 7, etc., if the accuracies of the

abbreviated values are to be more nearly the same for all. This can be made use of to advantage in tables of such approximate or abbreviated values. If, for instance, such a table is intended to be limited to three places of figures, the greatest error will be 0.5% for the low numbers (100) and 0.05% for the high ones (999); but by giving four places of figures for all numbers between 100 and 499, and three places for those from 500 to 999, making an increase of only 1 figure for every 6, or about 16%, the greatest error will be reduced fivefold, namely to 0.1%. The table will then take a mean position (in accuracy) between a three-place and a four-place table; the variations of the greatest errors in different parts of the table will, however, be the same in all three.

The location of the decimal point does not, of course, affect the percentage accuracy; thus 101., when it represents an approximate or abbreviated value, is just as accurately stated as 0.000 101 is.

A zero (0) at the right-hand end of a whole number may mean either a definite known quantity like a digit or an indefinite unknown one, merely filling a vacant place of figures; there is unfortunately no way of distinguishing between them. Thus in the value 5 280. feet to the mile, the zero might either mean that the last place of figures is exactly correct (which is the case in this particular value) or that only three places are correct and the fourth unknown. In a decimal fraction, however, a zero in the last place is always, or should always be, understood to be a definite known quantity; thus 0.150 is understood to be known or correct to three places, while 0.15 is known or correct to only two places.

The following table gives the errors in abbreviated numbers in a more concise form:

Abbreviated numbers.	Greatest error.	Mean probable error.
10	5.%	2.5%
50	1.%	0.5%
100	0.5%	0.25%
500	0.1%	0.05%
1 000	0.05%	25 parts in 100 000
5 000	0.01%	5 parts in 100 000
10 000	5 parts in 100 000	25 parts in 1 000 000
50 000	1 part in 100 000	5 parts in 1 000 000
100 000	5 parts in 1 000 000	25 parts in 10 000 000
500 000	1 part in 1 000 000	5 parts in 10 000 000

It will thus be seen that by using only three places of figures to represent any data or results (provided the last right-hand figure has been raised by unity when the next is 5 or over) the greatest possible error is only half a percent, and the probable mean error is about $\frac{1}{10}$ to $\frac{2}{10}$ %. Three places of figures therefore suffice for most engineering data.

In the more usual simple calculations with three-place values, the *mean probable error* in the result is in general no greater than this, but the *greatest possible error* becomes larger and may affect the third place by one unit. Successive multiplications like cubing increase the error. Hence if the result is to be quite correct to three places, then four places must be used to start with.

ACCURACY OF LOGARITHMS.

In general, the number of (decimal) places in the logarithms themselves should be one greater than the number of places of figures, in order to be as accurate (in percent) as the arithmetical calculations would be. The errors are therefore easily obtained from the above table for numbers. Four-place tables are therefore sufficiently accurate for three-place figures.

ABSOLUTE SYSTEM of UNITS. The C. G. S. SYSTEM.

Among the physical quantities there are some that are fixed, definite, independent of each other, and invariable all over the universe, while others are variable, indefinite, dependent, arbitrary, or involve empirical constants. A length, for instance, belongs to the former class and is invariable throughout the universe, while a weight considered as a force, is different on different parts of the earth or on different planets. The former are for the sake of a distinction, called *absolute quantities*.

Most physical quantities are dependent on others or are derived from others; for instance, a surface is the product of two lengths, and a velocity is a length passed through in a certain time. But there are a few that are independent of any others and may, therefore, be considered to be fundamental; a length, for instance, cannot be derived from anything else. By selecting three of the latter from among the absolute quantities most and perhaps all of the other physical quantities may be derived from them, or defined in terms of them, thus making a single uniform system in which all quantities can be expressed in terms of some function or combination of these three fundamental quantities. When a definite amount of each of these fundamental quantities is taken as a unit, such a system is called an *absolute system of units*.

Various systems of this kind have been devised differing in the three quantities which have been selected as the fundamental ones. The most important one and the only one which is in general use, is based on the three quantities, length, mass* and time, usually represented by the letters *L*, *M*, and *T* respectively, or *l*, *m*, and *t*, and when the unit amounts are taken as the centimeter, the gram (mass), and the second (mean solar), the system is called the centimeter-gram-second system, usually denoted as the *C. G. S. system*.

In this system the units of each of the derived quantities are the amounts which correspond to the unit amounts of those of the fundamental quantities which are involved. Thus the unit of velocity in this system is one centimeter per second; the unit of force, called a dyne, is that which acting on a mass of one gram at rest produces in one second a velocity of one centimeter per second; the unit of energy, called an erg, is one dyne of force acting through one centimeter; the unit of electricity or magnetic pole is that which attracts another equal amount at one centimeter distance, with a force of one dyne; etc., etc.

Sometimes the units of the derived quantities depend upon how they are defined, in which case there may be several different units. The most important case of this kind is that of the electrical units; in the one system, called the *electrostatic system*, a whole set of units is based on the definition that a unit of electricity is that which attracts an equal amount one centimeter distant, with a force of one dyne, while in the other, called the *electromagnetic system*, the unit current is defined as that which, flowing through an arc of one centimeter, curved to one centimeter radius, generates a unit magnetic pole at the center; this definition thus connects the unit of electricity with the unit of magnetism; on it the electrical units in common use are based. The relation between the two units of each electric quantity thus defined is found to be the velocity of light in the C. G. S. system, or some power of it.

* Mass represents amounts of matter and must be clearly distinguished from weight. A given mass of iron, for instance, is the same whether it be solid, liquid, volatilized, oxidized, dissolved, etc., and is the same all over the universe, while its weight is enormously greater on the sun than on the earth. Two given masses always have the same attraction of gravitation to each other at the same distance.

Sometimes the units thus defined are inconveniently large or small for practical purposes, and therefore certain *practical units* have been chosen which are made some multiple of 10 times as small or as large as the C. G. S. unit. Thus the ampere is $1/10$ and the volt is one hundred million times the C. G. S. unit (electromagnetic) of current and electromotive force respectively. The definitions of all these units and the relations between them are given in their respective places in the table of conversion factors.

While most physical quantities can thus be deduced from, or defined in terms of, the centimeter, the gram, and the second, yet it has not yet been possible to do this with all. Among the important exceptions are temperature, magnetic permeability, and electric inductive capacity; they should therefore be added to the fundamental quantities in defining or deducing some of the quantities. For most purposes the two latter may be, and in fact are, eliminated from consideration by making them equal to the numeral 1 or unity in the definitions. They are therefore called "suppressed" fundamental quantities.

There are in general two ways of establishing units of various quantities. One way is to define an absolute unit in accordance with the C. G. S. system, and then establish a concrete unit in terms of the absolute one, which will represent the latter or some simple decimal multiple of it, as closely as possible; this seems to be the more rational way, as it maintains the whole system uniform, although it is sometimes difficult to establish the concrete unit correctly; this is the method adopted in establishing the electrical and magnetic units. The other way is to arbitrarily establish the concrete unit first, by selecting some convenient standard, and then determining experimentally what its relation is to the natural, absolute unit; this is the method which was adopted in establishing the units of weight (considered as a force and not as a mass), heat, temperature, light, etc.; it has the disadvantage that the relations to other units then always involve an empirical constant which is necessarily incommensurate, like the acceleration of gravity, the mechanical equivalents of heat and of light; but it has the advantage that the concrete unit is established definitely at the start, and is not subject to occasional readjustment like the concrete electrical units.

DIMENSIONAL FORMULAS.

When any physical quantity is represented algebraically in terms of the fundamental quantities, the expression is called its dimensional formula. Thus, in the length, mass, and time or L , M , and T system, a surface which is the product of two lengths is represented by $L \times L$ or L^2 , a volume by L^3 ; these are the dimensional formulas of a surface and a volume, and the exponent of the letter is called its dimension.

It frequently happens in the more complex formulas, that some of these letters occur as divisors, that is, as the denominator of a fraction, and to avoid stating the formula in terms of a fraction, the exponents are made negative in such cases. Thus a velocity which is length divided by time, or L/T , is generally written LT^{-1} ; an acceleration is a velocity divided by time or LT^{-1}/T , which is written LT^{-2} ; a force is this multiplied by mass or $LM T^{-2}$ and energy is a force multiplied by a length or $L^2 M T^{-2}$, etc. Fractional exponents denote roots, thus $L^{\frac{1}{2}}$ means the square root of L ; or $L^{-\frac{3}{2}}$ denotes the cube of the square root of L in the denominator, etc.

In some cases the letters cancel each other, leaving the exponent 0; the dimensional formula is then simply 1, sometimes called a number; an angle, for instance, is defined as an arc divided by the radius, that is $L \div L = L^0 = 1$;

the same is true of an efficiency which is energy divided by energy, or power divided by power, etc.

When intelligently interpreted and applied, such dimensional formulas are often very useful. They frequently give an idea of the physical nature of a quantity, and more particularly of its relation to other quantities; they sometimes show that several quantities which have been defined in entirely different ways, and which originated differently, are really the same; they sometimes point out the existence of some law; they aid one in determining what the rational unit is, of a quantity for which no unit has been chosen; they are useful for finding whether a physical formula is correct and complete; these are only a few of the uses of such formulas. The quotient of two such formulas often shows that the relation between the quantities is a third simple, well-known quantity. Thus the relation between energy and pressure is a volume, or the relations between the formulas for the electrical units defined electrostatically, and those defined electromagnetically, is in this way shown to be the velocity of light or its square, which is one of the foundations of Maxwell's electromagnetic theory of light.

It must not be forgotten that the dimensional formulas usually used are based on the fundamental units, length, mass, and time, and that they would be quite different if other fundamental quantities are used; they are therefore only relative and not absolute, and their chief use is therefore to show the *relations* between different quantities rather than the physical nature of any one considered by itself.

Although dimensional formulas are very useful, great caution should be exercised in applying them, as inconsistencies and absurdities may result if they are treated as mere algebraic formulas. Energy, for instance, is $\text{force} \times \text{length}$, which gives the formula $L^2 M T^{-2}$, but torque is also $\text{force} \times \text{length}$, and therefore has the same formula, although it is physically an entirely different quantity. When torque acts through an angle it becomes energy, hence $\text{torque} \times \text{angle} = \text{energy}$, but as the dimensional formula of an angle is 1 the formula for torque is not changed by multiplying it by an angle. The length involved in torque is perpendicular to the force, while in energy it is in the same direction, therefore the two lengths have a different physical meaning in the two cases, as they are at right angles to each other; as this cannot be indicated in the formula, it shows that the system is defective. The "angle" in such a case has been termed a "suppressed quantity" in the formula, and it is due to such quantities that errors may arise in using dimensional formulas. Its real existence in the formula for torque should at least be indicated by some auxiliary letter like a , for instance, calling attention to its suppression in the rest of the formula.

It seems to have been impossible so far to find the true dimensional formula of temperature, or even to determine whether one exists; it is therefore safest at present to consider it an auxiliary fundamental quantity, usually represented by θ , and add it to the formula. Further remarks on this subject will be found in a footnote under the thermal units in the table of physical quantities given below.

In the formulas for the electrical and magnetic units there are also some "suppressed" quantities similar in some respects to the angle above mentioned; like in the case of temperature, their dimensional formulas are not known, they are generally omitted in the formulas for other derived quantities, but without them these formulas are not complete and may mislead. Ordinarily, they are considered to be unity and therefore are algebraically eliminated from the formulas, but as was shown above concerning the quantity "angle," this may lead to misconceptions. Until their dimensional formulas are known it is recommended to consider them as auxiliary fundamental quantities and to add to the formulas a symbol which represents them, in order to call attention to the fact that they really exist but are suppressed in the particular system used.* In the dimensional formulas given below in the table of physical quantities, they have been

* Prof. Ruecker, in the paper referred to below, says: "I think the symbols are thus made to express the limits of our knowledge and ignorance on the subject more exactly than if we arbitrarily assume that some one of the quantities is an abstract number."

added in parentheses; for ordinary purposes they may be considered as being unity. These quantities are the electric inductive capacity represented by k , and the magnetic permeability represented by μ . In the definitions of the *units* their values for air are assumed to be unity, which eliminates them quantitatively, but this is no reason why their dimensional formulas should be unity; a definition, for instance, might be based on a unit distance, but it would be quite wrong to therefore leave out of the dimensional formula the L which represents it.

Energy being always the same quantity in all systems, never has any of these suppressed factors in its formula; the same is true of power.

Although the dimensional formulas of these two suppressed quantities individually are unknown, that of both combined is known in the following form:

$$k^{-\frac{1}{2}} \mu^{-\frac{1}{2}} = LT^{-1} = v$$

in which v is the velocity of light in the C. G. S. system; hence when the formula of one of them is known, that of the other can be determined. It was thought by Williams (see reference below) that μ may be a density.

The dimensional formulas of the photometric quantities have, it seems, never been given. Those in the following table are suggested by the author.

A concise discussion of the deduction of the dimensional formulas of many of the usual physical quantities will be found in the Smithsonian Physical Tables, edited by Prof. Thomas Gray, 2d edit. p. xv to 4. The "suppressed" quantities are discussed in a paper by Ruecker in the Phil. Mag., Feb. 1889, vol. 27, p. 104, supplemented by another by Williams; Phil. Mag., 1892, p. 234. The table of physical quantities given below contains all the quantities whose formulas are given in these references besides numerous others.

DECISIONS OF INTERNATIONAL ELECTRICAL CONGRESSES

Concerning Electric, Magnetic, and Photometric Units and Definitions.

THE following is a brief summary of these decisions, adoptions, and recommendations.*

The official congress of 1881 in Paris adopted the **fundamental units** centimeter, gram (mass), and second, for the electric measures; the **ohm** as equal to 10^9 C. G. S. units†; the **volt** as equal to 10^8 C. G. S. units†; the **ampere** as the current produced by a volt through an ohm; the **coulomb** as the quantity corresponding to an ampere for one second; the **farad** as the capacity corresponding to a charge of a coulomb by a volt. It instructed an international commission to determine what the length of a column of mercury of one square millimeter cross-section must be, at 0° C., in order to have a resistance of one ohm as above defined; the commission reported in 1884 that this length was 106 centimeters and called this ohm the **legal ohm**; it also recommended that this be adopted internationally; it also recommended that the **ampere** be made equal to 10^{-1} C. G. S. (electromagnetic) units, and that the **volt** be that electromotive force which maintains a current of one ampere (presumably as just defined) through a resistance of one legal ohm; (this volt has since often been referred to as the **legal volt**, although there seems to be no legal sanction for this name). The congress of 1881 also recommended that an international commission be appointed to define a standard of light; this commission reported in 1884 that the **unit of each kind of simple light** be

* For a more detailed summary up to 1900 see *Récapitulation des Décisions des Congrès Antérieurs*, by Hospitalier, in the report entitled "Congrès International d'Électricité," 1900, pages 11-22; for the adoptions of the congress of 1900 see pages 369 and 370 of that report.

† The electromagnetic system was unquestionably meant, and is understood to be meant in all that follows here.

the quantity of light of the same kind emitted perpendicularly from a square centimeter of surface of melted platinum at the temperature of its solidification; and that the practical unit of **white light** be the total light thus emitted. (The name **violle** has since come into use for this unit, although apparently without official adoption.)

The official congress of 1889 in Paris adopted the **joule** as equal to 10^7 C. G. S. units of work (ergs) and defined it also as the energy represented per second by one ampere through one ohm; (the ohm here referred to is presumably that defined in terms of the absolute system, and not the "legal" ohm); the **watt** as equal to 10^7 C. G. S. units of power (ergs per second), and therefore equal to a joule per second; the **kilowatt** as the industrial unit of power in place of the horse-power; the **bougie décimale** (decimal candle) for the practical unit of light as equal to the twentieth part of the absolute standard of light defined by the commission in 1884 (namely, the platinum standard described above and called the **violle**); the **quadrant** for the practical unit of self-induction (now called inductance) as equal to 10^9 centimeters; the **period** of an alternating current was defined to be the duration of one complete oscillation, and the **frequency** the number of periods per second; the **mean intensity** (of a current) was defined by an algebraic expression which signifies the arithmetical average of all the instantaneous values; the **effective intensity** (of a current) was defined to be the square root of the mean square of the intensity of the current, and the **effective electromotive force**, the square root of the mean square of the electromotive force; the **apparent resistance** (now called impedance) was defined to be the factor by which the effective intensity of the current must be multiplied to give the effective electromotive force; the **positive plate** of an accumulator was defined to be that which is the positive pole during discharge.

The unofficial congress of 1891 at Frankfort (Germany) decided * that all units be expressed in Roman type, all physical quantities in italics, and all physical constants and angles in Greek type; also that the quantities ampere, coulomb, farad, joule, ohm, volt, and watt be expressed by their initial letters, A, C, F, J, O, V, and W. (These decisions were not confirmed by the subsequent official congress, and have not come into general use.)

The official congress of 1893 in Chicago † adopted the **international ohm**, based on the ohm equal to 10^9 C. G. S. units and represented by the resistance of a column of mercury at 0° C., 106.3 centimeters long, weighing 14.4521 grams, and having a uniform cross-section; (this cross-section, although not so stated officially, is practically one square millimeter); the **international ampere** as equal to 10^{-1} C. G. S. units, represented for practical purposes by the current which will deposit 0.001118 gram of silver per second; the **international volt** as that electromotive force which will maintain one international ampere through one international ohm, represented for practical purposes by $1 + 1.434$ of that of a Clark cell at 15° C.; the **international coulomb** as the quantity corresponding to one international ampere in one second; the **international farad** as corresponding to a charge of one international coulomb by one international volt; the **joule** as equal to 10^7 C. G. S. units, and represented in practice by the energy in one second of an international ampere passing through an international ohm; the **watt** as equal to 10^7 C. G. S. units and represented in practice by one joule per second; the **henry** as "the induction in a circuit when the electromotive force induced in this circuit is one international volt, while the inducing current varies at the rate of one ampere per second" (presumably meaning the international ampere). These eight units, substantially as defined by this international congress, were made legal in the United States by Act of Congress in 1894. For practical magnetic units, the C. G. S. units were commended by the Chicago congress, but no names were given them; a report of a committee on notation and nomenclature was received and ordered printed as an appen-

* See *Electrical World*, vol. 18, 1891, page 248.

† For further details see page 20 of the Proceedings of the International Electrical Congress held at Chicago, 1893, published by the Amer. Inst. Elect. Engineers.

dix, no further action being taken on it; (see the table of physical quantities below, in which that report is included).

The unofficial congress of 1896 in Geneva adopted the **bougie décimale** as the unit of intensity of light [I] equal to $\frac{1}{20}$ of a *violle*, but provisionally considered it to be represented in practice by the Hefner lamp; the **lumen** as the unit of flux of light [ϕ] equal to one bougie décimale for one solid angle; the **lux** as the unit of illumination [E] equal to one lumen per square meter; the **bougie per square centimeter** as the unit of brightness [e]; the **lumen-hour** as the unit of quantity of light [Q].

The official congress of 1900 in Paris adopted the name **gauss** for the C. G. S. unit of intensity of magnetic field or flux density, and the name **maxwell** for the C. G. S. unit of magnetic flux.

For the values of these official units in terms of each other and of other units, see the respective tables of measures.

TABLES of PHYSICAL QUANTITIES and RELATIONS.

The following table gives the physical quantities and relations in use, with their names, symbols, derivation, dimensional formulas in the C. G. S. system, and the units whenever such units have been generally adopted. A similar though much smaller table, limited chiefly to the more important electrical and magnetic quantities, was recommended by the Committee on Notation of the International Electrical Congress of 1893 in Chicago;* this has been included here after revision, correction, and some rearrangement. The "suppressed" factors k and μ have been added, which necessitated some changes in the derivational formulas of the Congress table, notably that of magnetic flux which now becomes BS instead of HS . The dimensional formulas then become consistent throughout; moreover, they then represent the conditions of practice better, as iron is used in nearly all forms of magnets.

The magnetic quantities based on the electrostatic system, which are not generally given in text-books, have here been added for the sake of completeness.

For the definitions of the units and the quantitative relations between them see the respective tables of measures.

* Reprinted with some additions in the "Electrical World and Engineer," vol. 37, January 5, 1901, p. 501.

PHYSICAL QUANTITIES AND RELATIONS.

Name.	Sym- bol.	Derivation.	Dimensional Formula.	'C. G. S. Unit.*
Fundamental.				
Length.....	L, l	.....	L	centimeter
Mass.....	M	.....	M	gram (mass)
Time.....	T, t	.....	T	second (mean solar)
<i>Auxiliary funda- mental quantities.</i>				
Temperature.....	θ	.....	θ	
Electric inductive capacity.....	k	.....	k	
Magnetic permea- bility.....	μ	.....	μ	
Geometric.				
Surface.....	S, s	LL	L^2	1 sq. centimeter
Volume.....	V	LLL	L^3	cubic centimeter
Angle, plane.....	a, β	$\frac{\text{arc}}{\text{radius}}$	number	radian
Angle, solid.....		$\frac{\text{spherical area}}{\text{radius}^2}$	number	1 sq. cm at 1 cm radius
Curvature or Tor- tuosity.....	$\left\{ \dots \right.$	$\frac{\text{angle}}{\text{length}}$	L^{-1}	
Specific curvature of a surface.....	$\left\{ \dots \right.$	$\frac{\text{solid angle}}{\text{surface}}$	L^{-2}	
Mechanical.				
Weight: see Mass and Force.				
Density.....	δ	$\frac{M}{V}$	$L^{-3}M$	gram (mass) per cb. cm
Specific gravity... sp. gr.		$\frac{\text{density}}{\text{density}}$	number	1
Force.....	F, f	Ma	LMT^{-2}	dyne
Intensity of attrac- tion or force at a point.....	$\left\{ \dots \right.$	$\frac{F}{M}$	LT^{-2}	dyne per gram
Gravitation con- stant.....	$\left\{ \dots \right.$	$\frac{FL^2}{M^2}$	$L^3M^{-1}T^{-2}$	
Force of a center of attraction or strength of a cen- ter.....	$\left\{ \dots \right.$	$\frac{FL^2}{M}$	L^3T^{-2}	
Surface tension... ..		$\frac{F}{L}$	MT^{-2}	dyne per centi- meter

* For the names and abbreviations of the numerous practical units and for their values in the C. G. S. units, see the various tables of measures.

PHYSICAL QUANTITIES AND RELATIONS (Continued).

Name.	Sym- bol.	Derivation.	Dimensional Formula.	C. G. S. Unit.
Pressure or intens- ity of stress. . . .	p	$\frac{F}{S}$	$L^{-1}MT^{-2}$	barie*
Modulus of elas- ticity.		$\frac{lF}{LS}$	$L^{-1}MT^{-2}$	
Resilience.		$\frac{W}{V}$	$L^{-1}MT^{-2}$	
Torque, moment, couple.		FL or $\frac{W}{\text{angle}}$	$L^2MT^{-2}\dagger$	dyne-centimeter
Directive force (as in suspensions). . .		$\frac{\text{torque}}{\text{angle}}$	L^2MT^{-2}	
Moment of inertia. . .	K	$M \times \text{radius}^2$	L^2M	gm (mass) cm sq.
Inertia.		$\frac{L^2M}{L}$	LM	
Velocity, linear. . .	v	$\frac{L}{T}$	LT^{-1}	centimeter per second; kine
Velocity, angular . .	ω	$\frac{\text{angle}}{T}$	T^{-1}	radian per second
Acceleration, lin- ear.	a	$\frac{v}{T}$	LT^{-2}	centimeter per sec. per sec.
Acceleration, an- gular.		$\frac{\omega}{T}$	T^{-2}	radian per sec. per sec.
Momentum or quantity of mo- tion.		mass $\times$ veloc- ity	LMT^{-1}	
Moment of mo- mentum or angu- lar momentum. . .		momentum $\times$ length	L^2MT^{-1}	
Energy, work. . . .	W	FL	L^2MT^{-2}	erg
Vis-viva.	W	$\frac{1}{2}Mv^2$	L^2MT^{-2}	erg
Impact.	W	$\frac{1}{2}Mv^2$	L^2MT^{-2}	erg
Power or activity..	P	$\frac{W}{T}$	L^2MT^{-3}	erg per second
Efficiency.		$\frac{\text{power}}{\text{power}}$	number	1%

* It equals a dyne per sq. centimeter. This name has not yet been definitely adopted; some use it for the pressure of one atmosphere.

† More correctly this should also contain the reciprocal of an angle.

PHYSICAL QUANTITIES AND RELATIONS (Continued)

Name.	Sym- bol.	Derivation.	Dimensional Formula.	C. G. S. and Practical Units.
Magnetic. (El'mag. system.)				
Reluctance or mag- netic resistance..	$\mathcal{R}$	$\nu \frac{L}{S}$	$L^{-1}(\mu^{-1})$	oersted *
Reluctivity; spe- cific reluctance..	ν	$\frac{1}{\mu}$	number $\times (\mu^{-1})$	
Permeance.....		$\frac{1}{\mathcal{R}}$	$L(\mu)$	
Magnetic capacity	$\mathcal{C}$	$\frac{1}{\mathcal{R}}$	$L(\mu)$	
Permeability or specific induc- tive capacity...	μ	$\frac{\mathcal{B}}{\mathcal{H}}$	number $\times (\mu)$	
Susceptibility. ...	κ	$\frac{\mathcal{J}}{\mathcal{H}}$	number $\times (\mu)$	
Magnetomotive force.	$\mathcal{F}$	$4\pi NI \dagger$	$L^{\frac{1}{2}} M^{\frac{1}{2}} T^{-1}(\mu^{-\frac{1}{2}})$	gilbert ¶
Magnetic poten- tial.....		$\frac{W}{m}$	$L^{\frac{1}{2}} M^{\frac{1}{2}} T^{-1}(\mu^{-\frac{1}{2}})$	
Magnetizing force.	$\mathcal{H}$	$\frac{\mathcal{F}}{L \dagger}$	$L^{-\frac{1}{2}} M^{\frac{1}{2}} T^{-1}(\mu^{-\frac{1}{2}})$	gilbert ¶ per cen- timeter; gauss
Field intensity. ...	$\mathcal{H}$	$\frac{F}{m}$	$L^{-\frac{1}{2}} M^{\frac{1}{2}} T^{-1}(\mu^{-\frac{1}{2}})$	gauss
Flux density.	$\mathcal{B}$	$\frac{\phi}{S}$	$L^{-\frac{1}{2}} M^{\frac{1}{2}} T^{-1}(\mu^{\frac{1}{2}})$	gauss
Magnetic induc- tion.....	$\mathcal{B}$	$\mu \mathcal{H}$	$L^{-\frac{1}{2}} M^{\frac{1}{2}} T^{-1}(\mu^{\frac{1}{2}})$	gauss
Intensity of mag- netization.....	$\mathcal{J}$	$\frac{\mathcal{M}}{V}$	$L^{-\frac{1}{2}} M^{\frac{1}{2}} T^{-1}(\mu^{\frac{1}{2}})$	
Flux or magnetic lines of force....	ϕ	$\mathcal{B}S$	$L^{\frac{1}{2}} M^{\frac{1}{2}} T^{-1}(\mu^{\frac{1}{2}})$	maxwell
Strength of pole or quantity of mag- netism.....	$\left. \begin{array}{l} m \\ \mathcal{M} \end{array} \right\}$	$\sqrt{L^2 F \mu}$	$L^{\frac{1}{2}} M^{\frac{1}{2}} T^{-1}(\mu^{\frac{1}{2}})$	
Magnetic moment.	$\mathcal{M}$	$ml.$	$L^{\frac{5}{2}} M^{\frac{1}{2}} T^{-1}(\mu^{\frac{1}{2}})$	
Magnetic energy...	W	$\phi \mathcal{F}$	$L^2 M T^{-2}$	erg
Magnetic power. .	P	$\phi \mathcal{F} n \S$	$L^2 M T^{-3}$	erg per second

* Provisionally adopted by the Amer. Inst. of Electrical Engineers.

† N = number of turns.‡ L = length of coil.§ n = frequency.

¶ Provisionally adopted by the Amer. Inst. Elec. Engineers. The usual unit is the ampere-turn. 1 gilbert = 0.795 8 ampere-turn.

PHYSICAL QUANTITIES AND RELATIONS (Continued).

Name.	Sym- bol.	Derivation.	Dimensional Formula.	Ratio of Electro- static to Elec' mag- n'ic Units*
Magnetic. (Electrostatic system.)				
Reluctance or magnetic resistance.	$\mathcal{R}$	$\frac{\mathcal{F}}{\phi}$	$LT^{-2}(k)$	v^2
Reluctivity; specific re- luctance.	ν	$\frac{1}{\mu}$	$L^2T^{-2}(k)$	v^2
Permeance.		$\frac{1}{\mathcal{R}}$	$L^{-1}T^2(k^{-1})$	v^{-2}
Magnetic capacity.	$\mathcal{C}$	$\frac{1}{\mathcal{R}}$	$L^{-1}T^2(k^{-1})$	v^{-2}
Permeability or specific inductive capacity. . . .	μ	$\frac{\mathcal{B}}{\mathcal{H}}$	$L^{-2}T^2(k^{-1})$	v^{-2}
Susceptibility.	κ	$\frac{\mathcal{I}}{\mathcal{H}}$	$L^{-2}T^2(k^{-1})$	v^{-2}
Magnetomotive force. . .	$\mathcal{F}$	$4\pi NI$	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-2}(k^{\frac{1}{2}})$	v
Magnetic potential.		$\phi\mathcal{R}$	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-2}(k^{\frac{1}{2}})$	v
Magnetizing force.	$\mathcal{H}$	$\frac{\mathcal{F}}{L}$	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-2}(k^{\frac{1}{2}})$	v
Field intensity.	$\mathcal{H}$	$\frac{F}{m}$	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-2}(k^{\frac{1}{2}})$	v
Flux density.		$\frac{\phi}{S}$	$L^{-\frac{1}{2}}M^{\frac{1}{2}}(k^{-\frac{1}{2}})$	v^{-1}
Magnetic induction.	$\mathcal{B}$	$\frac{\phi}{S}$	$L^{-\frac{1}{2}}M^{\frac{1}{2}}(k^{-\frac{1}{2}})$	v^{-1}
Intensity of magnetiza- tion	$\mathcal{I}$	$\frac{\mathcal{M}}{V}$	$L^{-\frac{1}{2}}M^{\frac{1}{2}}(k^{-\frac{1}{2}})$	v^{-1}
Flux (or magnetic lines of force)	ϕ	ET	$L^{\frac{1}{2}}M^{\frac{1}{2}}(k^{-\frac{1}{2}})$	v^{-1}
Strength of pole or quan- tity of magnetism.	m	$\frac{W}{\text{magn.poten.}}$	$L^{\frac{1}{2}}M^{\frac{1}{2}}(k^{-\frac{1}{2}})$	v^{-1}
Magnetic moment.	$\mathcal{M}$	ml	$L^{\frac{3}{2}}M^{\frac{1}{2}}(k^{-\frac{1}{2}})$	v^{-1}
Magnetic energy.	W	$\phi\mathcal{F}$	L^2MT^{-2}	1
Magnetic power.	P	$\frac{W}{T}$	L^2MT^{-3}	1

* v is the velocity of light in the C. G. S. system, namely 3×10^{10} centimeters per second. The factors μ and k are here neglected, as the square root of their product is the reciprocal of the velocity of light, and these ratios would therefore all become unity if these factors were included.

PHYSICAL QUANTITIES AND RELATIONS (Continued).

Name.	Symbol.	Derivation.	Dimensional Formula.	Practical Units.*
Electric.				
(El'mag. system.)				
Resistance.....	$R, r^\dagger$	$\frac{P}{I^2}$	$LT^{-1}(\mu)$	ohm
Resistivity or specific resistance..	ρ	$\frac{RS}{L}$	$L^2T^{-1}(\mu)$	ohm-centimeter
Reactance.....	$X, x^\dagger$	$2\pi nL - \frac{1}{2\pi nC}$	$LT^{-1}(\mu)$	ohm
Magnetic reactance.....	x_m	$2\pi nL$	$LT^{-1}(\mu)$	ohm
Capacity reactance or condensance.....	x_c	$\frac{1}{2\pi nC}$	$LT^{-1}(\mu)$	ohm
Impedance.....	$Z, z^\dagger$	$\sqrt{r^2 + x^2}$	$LT^{-1}(\mu)$	ohm
Conductance.....	$G, g^\dagger$	$\frac{1}{r}$ or $\frac{r}{z^2}$	$L^{-1}T(\mu^{-1})$	mho
Conductivity or specific conductance.....	γ	$\frac{1}{\rho}$	$L^{-2}T(\mu^{-1})$	mho per centimeter
Admittance.....	$Y, y^\dagger$	$\frac{1}{Z}$ or $\frac{1}{z}$	$L^{-1}T(\mu^{-1})$	mho
Susceptance.....	$B, b^\dagger$	$\sqrt{y^2 - g^2}$	$L^{-1}T(\mu^{-1})$	mho
Electromotive force.....	E, e	$\frac{\phi}{T}$	$L^{\frac{3}{2}}M^{\frac{1}{2}}T^{-2}(\mu^{\frac{1}{2}})$	volt
Potential.....		$\frac{W}{Q}$	$L^{\frac{3}{2}}M^{\frac{1}{2}}T^{-2}(\mu^{\frac{1}{2}})$	volt
Difference of potential.....	U, u	RI	$L^{\frac{3}{2}}M^{\frac{1}{2}}T^{-2}(\mu^{\frac{1}{2}})$	volt
Electromotive force at a point.....		$\frac{E}{L}$	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-2}(\mu^{\frac{1}{2}})$	volt
Intensity of electric field.....		$\frac{F}{Q}$	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-2}(\mu^{\frac{1}{2}})$	
Vector potential.....		$\frac{ET}{L}$	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-1}(\mu^{\frac{1}{2}})$	
Current.....	I, i	$\frac{E}{R}$	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-1}(\mu^{\frac{1}{2}})$	ampere
Current density.....		$\frac{I}{S}$	$L^{-\frac{3}{2}}M^{\frac{1}{2}}T^{-1}(\mu^{-\frac{1}{2}})$	ampere per sq. cm
Quantity of electricity; charge..	Q, q	IT	$L^{\frac{1}{2}}M^{\frac{1}{2}}(\mu^{-\frac{1}{2}})$	coulomb; ampere-hour
Surface density or electric displacement.....	ϵ	$\frac{Q}{S}$	$L^{-\frac{3}{2}}M^{\frac{1}{2}}(\mu^{-\frac{1}{2}})$	coulomb per sq. cm

* The C. G. S. units have no names. For the relations between the values of these units and the C. G. S. units, see the various tables of measures.

† Vector quantities when used should be denoted by capital italics.

PHYSICAL QUANTITIES AND RELATIONS (Continued).

Name.	Sym- bol.	Derivation.	Dimensional Formula.	Practical Units.
Capacity.....	C, c	$\frac{Q}{E}$	$L^{-1}T^2(\mu^{-1})$	micro-farad
Electric inductive capacity, or Di- electric constant, or Specific induc- tive capacity....	k	$\frac{C}{L}$	$L^{-2}T^2(\mu^{-1})$	
		$\frac{C}{L} + \frac{C}{L}$	number	
Inductance or co- efficient of self- induction or elec- tro-kinetic iner- tia.....	L, l	$\frac{N\phi^*}{I}$	$L(\mu)$	henry
Mutual inductance			$L(\mu)$	henry
Inductance factor: see below.				
Time constant.		$\frac{L}{R}$	T	second; henry per ohm
Period.		$\frac{1}{n}$	T	second
Frequency.....	n		T^{-1}	periods per sec.
Angular velocity..	ω	$2\pi n$	T^{-1}	radians per sec.
Electro-kinetic momentum.		$I \times \text{inductance}$	$L^{\frac{3}{2}}M^{\frac{1}{2}}T^{-1}(\mu^{\frac{1}{2}})$	
Thermoelectric height or specific heat of electricity	$\left\{ \begin{array}{l} \dots \\ \dots \end{array} \right.$	$\frac{E}{\theta^\dagger}$	$L^{\frac{3}{2}}M^{\frac{1}{2}}T^{-2}\theta^{-1}(\mu^{\frac{1}{2}})$	
Coefficient of Pel- tier effect.....		$\frac{\text{heat}}{IT}$	$L^{-\frac{1}{2}}M^{\frac{1}{2}}\theta(\mu^{\frac{1}{2}})$	
Ditto.....		$\frac{\text{energy}}{IT}$	$L^{\frac{3}{2}}M^{\frac{1}{2}}T^{-2}(\mu^{\frac{1}{2}})$	
Electric energy...	W	EQ	L^2MT^{-2}	joule; watt-hour
Kinetic energy....	W	I^2L	L^2MT^{-2}	joule
Electric power....	P	$\frac{EQ}{T}$	L^2MT^{-3}	watt; kilowatt
Power factor.....		$\frac{\text{real } P}{\text{apparent } P}$	number	1
Inductance factor.		$\frac{\text{wattless } P}{\text{apparent } P}$	number	1
Electrochemi- cal.				
(El' mag. system.)				
Ionic charge.		$\frac{Q}{M}$	$L^{\frac{1}{2}}M^{\frac{1}{2}}(\mu^{-\frac{1}{2}})$	coulomb per uni- valent gram ion
Electrochemical equivalent.....		$\frac{M}{Q}$	$L^{-\frac{1}{2}}M^{\frac{1}{2}}(\mu^{\frac{1}{2}})$	gram per cou- lomb
Electric deposition		$\frac{M}{T}$	MT^{-1}	gram per second

* N = number of turns.† θ = temperature.

PHYSICAL QUANTITIES AND RELATIONS (*Continued*).

Name.	Sym- bol.	Derivation.	Dimensional Formula.	Ratio of Electro- static to Elec'mag- netic Units.
Electric. (Electrostatic system.)				
Resistance.....	R, r	$\frac{E}{I}$	$L^{-1}T(k^{-1})$	v^{-2}
Resistivity or specific resistance.....	ρ	$\frac{1}{r}$	$T(k^{-1})$	v^{-2}
Reactance.....	X, x	$x_m - x_c$	$L^{-1}T(k^{-1})$	v^{-2}
Magnetic reactance....	x_m	$2\pi nL$	$L^{-1}T(k^{-1})$	v^{-2}
Capacity reactance or condensance.....	$\left\{ x_c \right.$	$\frac{1}{2\pi nC}$	$L^{-1}T(k^{-1})$	v^{-2}
Impedance.....	Z, z	$\sqrt{r^2 + x^2}$	$L^{-1}T(k^{-1})$	v^{-2}
Conductance.....	G, g	$\frac{I}{E}$	$LT^{-1}(k)$	v^2
Conductivity or specific conductance.....	γ	$\frac{Q}{STE/L}$	$T^{-1}(k)$	v^2
Admittance.....	Y, y	$\frac{1}{z}$	$LT^{-1}(k)$	v^2
Susceptance.....	B, b	$\sqrt{y^2 - g^2}$	$LT^{-1}(k)$	v^2
Electromotive force or potential.....	E, e	$\frac{W}{Q}$	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-1}(k^{-\frac{1}{2}})$	v^{-1}
Difference of potential	U, u	$e_1 - e_2$	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-1}(k^{-\frac{1}{2}})$	v^{-1}
Electromotive force at a point.....	$\left\{ \dots \right.$	$\frac{E}{L}$	$L^{-\frac{1}{2}}M^{\frac{1}{2}}T^{-1}(k^{-\frac{1}{2}})$	v^{-1}
Intensity of electric field		$\frac{F}{Q}$	$L^{-\frac{1}{2}}M^{\frac{1}{2}}T^{-1}(k^{-\frac{1}{2}})$	v^{-1}
Vector potential.....		$\frac{ET}{L}$	$L^{-\frac{1}{2}}M^{\frac{1}{2}}(k^{-\frac{1}{2}})$	v^{-1}
Current.....	I, i	$\frac{Q}{T}$	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-2}(k^{\frac{1}{2}})$	v
Current density.....		$\frac{I}{S}$	$L^{-\frac{1}{2}}M^{\frac{1}{2}}T^{-2}(k^{\frac{1}{2}})$	v
Quantity of electricity, charge.....	Q, q	$\sqrt{L^2F}$	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-1}(k^{\frac{1}{2}})$	v
Surface density or elec- tric displacement.....	$\left\{ \dots \right.$	$\frac{Q}{S}$	$L^{-\frac{1}{2}}M^{\frac{1}{2}}T^{-1}(k^{\frac{1}{2}})$	v
Capacity.....	C, c	$\frac{Q}{E}$	$L(k)$	v^2
Electric induction ca- pacity or Dielectric constant or specific in- ductive capacity.....	$\left. \begin{matrix} \\ \\ \end{matrix} \right\} k \left\{ \right.$	$\frac{C}{L}$	number (k)	v^2
		$\frac{C}{L} \div \frac{C}{L}$	number	1

PHYSICAL QUANTITIES AND RELATIONS (Continued).

Name.	Sym- bol.	Derivation.	Dimensional Formula.	Ratio of Electro- static to Elec'mag- netic Units.
Inductance or coefficient of self-induction or electrokinetic inertia. .	$\left. \begin{array}{l} L, l \end{array} \right\}$	$\frac{xm}{2\pi n}$	$L^{-1}T^2(k^{-1})$	v^{-2}
Mutual inductance. ....		.....	$L^{-1}T^2(k^{-1})$	v^{-2}
Time constant.....		$\frac{L}{R}$	T	1
Period.		$\frac{1}{n}$	T	1
Frequency.	n	.....	T^{-1}	1
Electrokinetic momen- tum.		$I \times \text{inductance}$	$L^{\frac{1}{2}}M^{\frac{1}{2}}(k^{-\frac{1}{2}})$	v^{-1}
Thermo-electric height or specific heat of elec- tricity.	$\left. \begin{array}{l} \dots \dots \dots \end{array} \right\}$	$\frac{E}{\theta}$	$\frac{L^{\frac{1}{2}}M^{\frac{1}{2}}}{T\theta(k^{\frac{1}{2}})}$	v^{-1}
Coefficient of Peltier ef- fect.		$\frac{\text{heat}}{IT}$	$L^{-\frac{1}{2}}M^{\frac{1}{2}}T\theta(k^{-\frac{1}{2}})$	v^{-1}
Ditto.		$\frac{\text{energy}}{IT}$	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-1}(k^{-\frac{1}{2}})$	v^{-1}
Electric energy.	W	$\frac{EQ}{T}$	L^2MT^{-2}	1
Electric power.	P	$\frac{W}{T}$	L^2MT^{-3}	1
Electrochemical.				
(Electrostatic system.)				
Ionic charge.		$\frac{Q}{M}$	$L^{\frac{1}{2}}M^{-\frac{1}{2}}T^{-1}(k^{\frac{1}{2}})$	v
Electrochemical equiva- lent.		$\frac{M}{Q}$	$L^{-\frac{1}{2}}M^{\frac{1}{2}}T(k^{-\frac{1}{2}})$	v
Electric deposition.		$\frac{M}{T}$	MT^{-1}	1
Photometric.*				
Quantity of light.....	Q	ϕT	L^2MT^{-2}	Unit. lumen hour
Flux of light.	ϕ	$\frac{Q}{T}$	L^2MT^{-3}	lumen
Intensity of light	I	$\frac{\phi}{\text{solid angle}}$	L^2MT^{-3}	candle; hef- ner
Brightness.	e	$\frac{I}{S}$	MT^{-3}	candle per sq. cm
Illumination.	E	$\frac{\phi}{S}$	MT^{-3}	lux

* The dimensional formulas for the photometric quantities here given have been deduced by the author on the basis that radiated light is power, or that quantity of light is energy; according to this, the formula for candle-power is that for power divided by that for a solid angle; the latter, having the dimensional formula 1 in the C. G. S. system, is a "suppressed" factor which does not appear in the formula.

PHYSICAL QUANTITIES AND RELATIONS (Concluded).

Name.	Symbol.	Derivation.	Dimensional Formulas.†			
			Dynamical	Thermal	Thermo- metric.	$\theta = H + M.$
Thermal.*						
Heat.....	H	energy	L^2MT^{-2}	$M\theta$	$L^3\theta$	L^2MT^{-2}
Rate of heat production...	$\left\{ \right.$	$\frac{H}{T}$	L^2MT^{-3}	$MT^{-1}\theta$	$L^3T^{-1}\theta$	L^2MT^{-3}
Temperature..		.....	$\theta\ddagger$	$\theta\ddagger$	$\theta\ddagger$	L^2T^{-2}
Coefficient of expansion....	θ	$\frac{(V - V')}{V(\theta - \theta')}$	θ^{-1}	θ^{-1}	θ^{-1}	$L^{-2}T^2$
Entropy.....		$\frac{H}{\theta}$	$L^2MT^{-2}\theta^{-1}$	M	L^3	M
Latent heat....		$\frac{H}{M}$	L^2T^{-2}	θ	$L^3M^{-1}\theta$	L^2T^{-2}
Conductivity...		$\frac{HL}{TL^2\theta}$	$LMT^{-3}\theta^{-1}$	$L^{-1}MT^{-1}$	L^2T^{-1}	$L^{-1}MT^{-1}$
Emissivity or immissivity...		$\frac{H}{TL^2\theta}$	$MT^{-3}\theta^{-1}$	$L^{-2}MT^{-1}$	LT^{-1}	$L^{-2}MT^{-1}$
Specific heat. ...		$\frac{H}{H}$	number	number	number	number
Capacity.....		$M \times \text{sp. heat}$	M	M	M	M
Mechanical equivalent....	J	$\frac{\text{mec. energy}}{\text{heat-energy}}$	number	$L^2T^{-2}\theta^{-1}$	$\frac{M}{LT^2\theta}$	number

* For the names and definitions of heat-units see tables of units of Energy.

† The dimensional formulas of the various thermal quantities or relations are still a matter of some conjecture, excepting only that of quantity of heat, which is simply energy, and that of the rate of production or transmission of heat or radiant heat, which is simply power; that of temperature is the uncertain factor. For this reason four different systems are here given, based on four different fundamental conceptions. The first is based on the dynamical units, that is, on the formula of energy combined with a fourth fundamental unit representing temperature. The second is based on the thermal units; quantity of heat then is mass $\times$ temperature; in this system the specific heat of water is unity by definition and is therefore suppressed in the formula. In the third system volume is substituted for mass in the second. In the fourth system the author has eliminated θ by defining temperature as energy per unit of mass, that is, as specific mass energy. Most of the data in columns 3, 4, 5, and 6 have been taken from the Smithsonian Physical Tables prepared by Prof. Thomas Gray; the present author has extended them and supplied some omissions; the new matter has been approved by Prof. Gray.

‡ By giving θ the dimensional formula L^2T^{-2} , those based on the dynamical units and on the thermal units become identical; they are given in the last column. Or by making it $L^{-1}MT^{-2}$, those based on the dynamical and the thermometric units become identical. L^2T^{-2} is the dimensional formula of energy per unit of mass, and $L^{-1}MT^{-2}$ is that of pressure. Ruecker suggests giving θ the formula L^2MT^{-2} , which is energy. No great importance should be attached to attempts to give temperature a formula, as they are all merely speculative.

TABLES OF CONVERSION FACTORS.

GENERAL REMARKS.

In the following set of tables every unit which is used to measure quantities is given with its value in terms of the other units of its kind. Such numbers are variously termed values, reduction or conversion factors, equivalents, relations, ratios, constants, etc.; they give the relations between the different units and enable one to reduce each one (or a quantity measured by it) to the other (or a quantity measured by it) by means of a single multiplication. The table includes all the values and relations usually given in books under the title of "Weights and Measures," although these form only a very small part, as by far the greater number have never before been published together as a complete set of values.

The term "Weights and Measures" has not been used in connection with these tables, partly because it is not apparent why weights are not also measures, and partly because the present tables consist largely of various measures rarely if ever given in books under the title of weights and measures.

Owing to the very large number of units belonging in such a table, their classification and arrangement becomes important in order to enable one to find any particular unit readily. All units for measuring the same quantity, that is, all units of length for instance, or all units of volume, etc., have here been brought together in one group, and in each group they are arranged in the order of their size; all the different values of each unit are also arranged in order of size.

To give the value of each unit in terms of each of the others would have made the tables many times as long, and they would have become unnecessarily cumbersome, as the majority of the values are never used; the number of values or reduction factors have therefore been limited to those likely to occur in practice; if the others are ever needed they can readily be found from these.

To avoid unnecessary repetition of values, all units capable of being reduced from one to the other have here been put in the same group. Thus the group of units of volumes includes both cubical units such as cubic feet, etc., as well as capacity measures, such as gallons, liters, etc. All energy units are similarly grouped together, whether they be mechanical, thermal, or electrical. In a few cases, however, such units have been separated into different groups; forces, for instance, have not been given together with weights, although they are interconvertible, and electrical resistances have been given separately and not with velocities, although in the C. G. S. electromagnetic system of units they are velocities.

Sometimes some of the units in one group are for measuring entirely different kinds of quantities, and even have entirely different dimensions, yet their equivalents are the same, and they have therefore been brought together to save repetition; for instance, pounds per square foot may denote either a pressure or the weight of sheet metal; in either case the equivalents in other units, such as kilograms per square meter, will be the same. Similarly, grams per centimeter may denote either the weights of a wire or

a surface tension, yet its equivalents in other units are the same. Power and momentum, or energy and torque, are other illustrations.

In the case of lengths, surfaces, volumes, and weights (masses) there are so many unusual, special trade, obsolete, or foreign units the values or reduction factors of which are not often needed, that they have been grouped separately, so as to make the main table less cumbersome to use.

The reciprocal values have been given in all cases in which it was thought they were likely to occur in practice, thus reducing all calculation to a mere multiplication, as distinguished from a long division. They are given in their proper places, and one should therefore first look for the units that one wants. Thus to convert meters into feet, see value under Meters, and to convert feet into meters, see value under Feet.

Special attention is here called to the approximate values which have been given in nearly every case. These have been carefully chosen with a view to reduce the calculation to the smallest possible, generally to a multiplication by one digit and a division by another single digit, followed by pointing off the decimal. They are believed to be the simplest values that exist. The accuracy of all these approximate values is within 2% and often within 1%; they are therefore sufficient for most calculations.

The symbols or abbreviations which are given are either those in common use or those which have been recommended by societies, journals, or individuals, and in a few unimportant cases where none existed they have been supplied by the author in conformity with the others. The advantages and desirability of a uniform and universal system of abbreviations or symbols are too evident to need further comment here.

This whole system of tables, which is not a compilation but a complete recalculation, has been based on the very best fundamental values that are obtainable. Their numerical values are given in their respective places or in the introductory notes; they are printed in bold-faced type. Whenever legally adopted values existed, as for instance for the relations between the metric and the older units, they have been used. In other cases the fundamental values have been obtained from the best existing sources, and wherever possible those values have been chosen which have been determined upon by the best authorities and are used by them. The chief of these authorities was the National Bureau of Standards, from which the author has obtained the legal values and all the other standard values used or recommended by it, besides much valuable assistance; among the others were the International Congresses, the Director of the Nautical Almanac, the Coast Survey Department, etc. The greatest care was taken in obtaining all these fundamental values, and it is believed that they are the best which exist at the present time. They are limited to only those which are absolutely necessary, as was explained above under the inter-relations of units, and none of them is therefore inconsistent with any other, nor can any derived value then have two values depending upon which way it has been calculated from the fundamental values; all the values together form a single, uniform, stable system.

The fundamental values have here been given to as many places of figures as in the original source. The derived values have been given throughout to six significant figures. In some cases the fundamental value itself may not have six figures, or its possible error may not warrant so many places of figures in the derived units; but in such a completely recalculated set of values it was thought best to retain six places of significant figures throughout in all the derived values, as the correction due to any subsequently adopted more accurate fundamental value can then be made by mere proportion instead of by a complete recalculation. The derived values are exactly correct for the particular fundamental values used here, excepting of course the usual slight inaccuracy (± 1) of the last right-hand digit in the numbers and in the logarithms.

The calculations have all been made with the greatest care; each was checked by calculating it in another way and in many cases the values were thus checked twice; it is therefore believed that there are no errors. There is, of course, the unavoidable uncertainty of one unit in the sixth place of figures or in the seventh place of the logarithms, although in most of these cases the next place was also calculated in order to insure the accuracy of those that were retained. Many of the values in the first few groups have been carefully checked by L. A. Fischer, Assistant Physicist of the National Bureau of Standards, and may therefore be assumed to be those used by

that Bureau. The author takes this opportunity to acknowledge his appreciation of Mr. Fischer's very valuable revision of those values.

The obsolete and foreign units were compiled from various sources. They therefore involve any inaccuracies or inconsistencies that may exist in the original sources; but when the inconsistency was very great, care was taken to find which value was the correct one.

In the cases in which units are sometimes used incorrectly or ambiguously, they have here also been placed where they might be looked for, and are there accompanied by a reference to the place where they properly belong and where their values are given.

A comparison of the values in these tables with those in other books will show that few of the latter have been based on the legal standards of this country. Moreover, the older published values will often be found to be inconsistent with each other, as they seem to have been compiled instead of being recalculated throughout from the same fundamental values, as was done here.

Special attention is called to the compound units, most of which are seldom, if ever, found in other books; as most of these save from two to four separate calculations, they will often be found useful.

LENGTHS.

The fundamental standard of length of the United States is the International Meter, a bar made of an alloy of 90 percent platinum and 10 percent iridium and preserved at the International Bureau of Weights and Measures, near Paris. Copies of this bar are possessed by each of the twenty countries contributory to the support of the International Bureau of Weights and Measures, and these copies are known as National Prototypes. The United States owns two of these bars, whose values in terms of the International Meter are known with the greatest accuracy. One of these bars, No. 21, is used as a working standard, and the other, No. 27, is kept under seal and only used to check the value of No. 21. One of the objects of the maintenance of the International Bureau is to provide for the recomparison at regular intervals of the various National Prototypes with the International Meter, thus insuring the use of the same standard throughout the world.

According to the Act of Congress of July 28, 1866, which was the first general legislation in the United States upon the subject of fixing the standards of weights and measures, the relation 1 meter = 39.370 0 inches was legalized, and it is the only legal relation which exists in the United States concerning the meter. This value is the one used by the National Bureau of Standards in Washington and is in general use in this country. Since 1893 the Office of Standard Weights and Measures has been authorized to derive the yard from the meter in accordance with this relation; the legal yard, foot, inch, etc., are therefore *derived from the meter*, and consequently are fixed and definite units. The relation between the U. S. yard and the meter is therefore no longer to be determined by measurement, as is often supposed, but is fixed definitely by precise definition. There is no legal authority in this country for the old Kater relation of 1818, namely, 39.370 79, which is still in use, notably by one well-known maker of gauges.

In Great Britain the relation, legalized in 1896, between this same International Meter and the British Imperial yard of 36 inches is 1 meter = 39.370 113 inches. The Kater value, 39.370 79, was used there for trade purposes until 1896. In 1867 the Clark value, 39.370 432, was recommended by the Warden of Standards, London, to supersede the Kater value, and was generally used in scientific work in Great Britain until 1896. There exists therefore a very slight difference between the present U. S. and British legal yard, foot, inch, etc. But these differences are only about 3 parts in one million, the U. S. yard being the longer; it is therefore absolutely negligible except in the most refined physical measurements. Unless otherwise stated, the values in the following tables are based on the U. S. legal relation.

The value of the nautical mile in meters (1 853.25) is the one adopted many years ago by the U. S. Coast and Geodetic Survey, and has not been changed since its first adoption. It is the length of one minute of arc of a great circle of a true sphere whose area is equal to that of the earth. The "Committee Meter" used by the U. S. Coast and Geodetic Survey prior to 1889 is equal to the international meter of 39.370 0 inches (U. S.).

LENGTHS. Usual.

** Accepted by the National Bureau of Standards.

* Checked by L. A. Fischer, Asst. Phys. National Bureau of Standards.

Aprx. means within 2%.

		Logarithm
1 mil	= 0.025 400 05* millimeter. Aprx. $\frac{1}{40}$	2.404 8346
"	= 0.001 inch.....	3.000 0000
1 millimeter [mm]	= 39.370 0* mils. Aprx. 40.....	1.595 1654
"	= 0.039 370 0* inch. Aprx. $\frac{1}{25}$	2.595 1654
"	= 0.001 meter.....	3.000 0000
1 centimeter [cm]	= 0.393 700* inch. Aprx. $\frac{4}{10}$	1.595 1654
"	= 0.032 808 3* foot. Aprx. $\frac{1}{30}$	2.515 9842
"	= 0.01 meter.....	2.000 0000
1 inch [in]	= 1 000. mils.	3.000 0000
"	= 25.400 05* millimeters. Aprx. $\frac{1}{4} \times 100$	1.404 8346
"	= 2.540 005* centimeters. Aprx. $\frac{1}{4}$	0.404 8346
"	= 0.083 333 3* foot or $\frac{1}{12}$	2.920 8188
"	= 0.027 777 8* yard or $\frac{1}{36}$. Aprx. $\frac{1}{4} \div 100$	2.443 6975
"	= 0.025 400 05* meter. Aprx. $\frac{1}{40}$	2.404 8346
1 decimeter [dm]	= 10. centimeters.....	1.000 0000
"	= 3.937 00* inches. Aprx. 4.....	0.595 1654
"	= 0.328 083* foot. Aprx. $\frac{1}{3}$	1.515 9842
"	= 0.109 361* yard. Aprx. $\frac{1}{9}$	1.038 8629
"	= 0.1 meter.....	1.000 0000
1 foot [ft] (Brit.)	= 0.999 997 1* foot (U. S.). Aprx. 1.....	1.999 9988
"	= 0.304 800* meter. Aprx. $\frac{3}{10}$	1.484 0146
1 foot [ft] (U. S.)	= 304.801* millimeters. Aprx. 300.....	2.484 0158
"	= 30.480 1* centimeters. Aprx. 30.....	1.484 0158
"	= 12. inches.....	1.079 1812
"	= 3.048 01* decimeters. Aprx. 3.....	0.484 0158
"	= 1.000 002 9* feet (Brit.). Aprx. 1.....	0.000 0012
"	= 0.333 333 yard or $\frac{1}{3}$	1.522 8787
"	= 0.304 801* meter. Aprx. $\frac{3}{10}$	1.484 0158
"	= 0.000 304 801* kilometer. Aprx. 3 ÷ 10 000.....	4.484 0158
"	= 0.000 189 394* mile. Aprx. 19 ÷ 100 000.....	4.277 3661
1 yard [yd] (Brit.)	= 0.999 997 1* yard (U. S.). Aprx. 1.....	1.999 9988
"	= 0.914 399 2* meter. Aprx. $\frac{9}{10}$ or $1\frac{1}{11}$	1.961 1359
1 yard [yd] (U. S.)	= 91.440 2* centimeters. Aprx. 90.....	1.961 1371
"	= 36. inches.....	1.556 3025
"	= 3. feet.....	0.477 1213
"	= 1.000 002 9* yards (Brit.). Aprx. 1.....	0.000 0012
"	= 0.914 402** meter. Aprx. $\frac{9}{10}$ or $1\frac{1}{11}$	1.961 1371
"	= 0.000 914 402* kilomt'r. Aprx. $\frac{1}{11} \div 100$	4.961 1371
"	= 0.000 568 182* mile. Aprx. $\frac{4}{7} \div 1 000$	4.754 4873
1 meter [m]	= 1 000. millimeters.....	3.000 0000
"	= 100. centimeters.....	2.000 0000
"	= 39.370 113* inches (Brit.). Aprx. 40.....	1.595 1666
"	= 39.370 000** inches (U. S.). Aprx. 40.....	1.595 1654
"	= 10. decimeters.....	1.000 0000
"	= 3.280 83** feet. Aprx. $\frac{1}{3}$	0.515 9842
"	= 1.093 61** yards. Aprx. $\frac{1}{10}$	0.038 8629
"	= 0.546 806* fathom. Aprx. $\frac{1}{20}$	1.737 8329
"	= 0.001 kilometer.....	3.000 0000
"	= 0.000 621 370* mile. Aprx. $\frac{5}{8} \div 1 000$	4.793 3503
1 kilometer [km]	= 3 280.83* feet. Aprx. $\frac{1}{3} \times 10 000$	3.515 9842
"	= 1 093.61* yards. Aprx. 1100.....	3.038 8629
"	= 1 000. meters.....	3.000 0000
"	= 0.621 370* mile. Aprx. $\frac{5}{8}$	1.793 3503
"	= 0.539 611 knot (Brit.). Aprx. $\frac{6}{11}$	1.732 0808
"	= 0.539 593 nautical mile (U. S.) Aprx. $\frac{6}{11}$	1.732 0660

1 mile [ml]=same as statute mile or land mile.

"	=	5 280.* feet.	Aprx. 5 300.....	3.722 6339
"	=	1 760.* yards.	Aprx. $\frac{3}{4} \times 1\ 000$	3.245 5127
"	=	1 609.35* meters.	Aprx. 1 600.....	3.206 6497
"	=	1.609 35* kilometers.	Aprx. add $\frac{9}{10}$	0.206 6497
"	=	0.868 421 knot (Brit.).	Aprx. subtract $\frac{1}{8}$	1.938 7303
"	=	0.868 392 nautical mile (U.S.).	Aprx. subtr. $\frac{1}{8}$..	1.938 7157

1 knot or nautical mile (Brit.):

=	6 080.	feet.	Aprx. 6 000.....	3.783 9036
=	2 026.67	yards.	Aprx. 2 000.....	3.306 7823
=	1.853 19	kilometers.	Aprx. $\frac{11}{16}$	0.267 9194
=	1.151 52	miles.	Aprx. add $\frac{1}{4}$	0.061 2697
=	0.999 966	nautical mile or knot (U.S.).	Aprx. 1.....	1.999 9854

1 nautical mile or knot (U.S.) same as geographical or sea mile:

=	6 080.20	feet.	Aprx. 6 000.....	3.783 9182
=	2 026.73	yards.	Aprx. 2 000.....	3.306 7969
=	1 853.25	meters.	Aprx. $\frac{11}{16} \times 1\ 000$	3.267 9340
=	1.853 25	kilometers.	Aprx. $\frac{11}{16}$	0.267 9340
=	1.151 55	miles.	Aprx. add $\frac{1}{4}$	0.061 2843
=	1.000 034	knots (Brit.).	Aprx. 1.....	0.000 0146
=		1 minute of earth's circumference	.....	0.000 0000

LENGTHS (continued). Unusual, Special Trade, or Obsolete.

1 Angstroem unit (spectroscopy)=0.1 milli-micron, or micro-milli-meter = 0.000 1 micron = 0.000 003 937 00 mil = 0.000 000 1 millimeter.
1 mil=254 000.5 Angstroem units.

1 milli-micron [$\mu\mu$] (spectroscopy) or **micro-millimeter** (microscopy)=10 Angstroem units=0.001 micron=0.000 039 370 0 mil=0.000 001 millimeter. **1 mil**=25 400.1 milli-microns. The term micro-millimeter is also used, though incorrectly, in biology for 0.001 millimeter, which length is more properly called a micron or micro-meter.

1 wave length of blue light is of the order of about 5000 Angstroem units or 500 milli-microns or 0.5 micron or 0.02 mil. For accurate values see below under meter.

1 micron or microne or micro-meter [μ] (spectroscopy and microscopy)=10 000 Angstroem units=1 000 milli-microns or micro-millimeters=0.039 370 0 mil (aprx. $\frac{1}{25}$)=0.001 millimeter. **1 mil**=25.400 1 microns.

1 terze (Brit.)= $\frac{1}{12}$ second= $\frac{1}{144}$ line= $\frac{1}{1728}$ inch.

1 second (Brit.)=12. terzes= $\frac{1}{12}$ line= $\frac{1}{144}$ inch.

1 point=0.008 inch.

1 point (typography)= $\frac{1}{6}$ line= $\frac{1}{72}$ inch.

1 line (U. S.)= $\frac{1}{12}$ inch.

1 line (Brit.)=144. terzes=12. seconds= $\frac{1}{12}$ inch. Also given as $\frac{1}{10}$ inch.

1 hairsbreadth= $\frac{1}{4}$ line= $\frac{1}{48}$ inch.

1 barleycorn= $\frac{1}{3}$ inch.

1 nail [na] (cloth)=2 $\frac{1}{4}$ inches= $\frac{1}{4}$ span.

1 palm=3. inches.

1 hand=4. inches.

1 link [li] (surveyor's)=7.920 0 inches=0.201 17 meter.

1 link [li] (engineer's)=12. inches=1. foot=0.304 80 meter.

1 span=9. inches=4. nails=1. quarter= $\frac{1}{4}$ yard.

1 quarter [qr] (cloth)=9. inches=4. nails=1. span= $\frac{1}{4}$ yard.

1 cubit=18. inches=1 $\frac{1}{2}$ feet.

1 cubit (in Bible)=21.8 inches.

1 vara (California; legal)=33.372 inches.

1 pace=3. feet.

1 military pace=3. feet.

1 common pace=2 $\frac{1}{2}$ feet.

1 meter used by Pratt & Whitney Co.=39.370 79 inches=1.000 020 meters (int.).

- 1 **meter** = 1 553 163.5 wave lengths of red light.†
 = 1 966 249.7 " " " green " †
 = 2 083 372.1 " " " blue " †
- 1 **Committee Meter** (of U. S. Coast Survey) = 39.370 0 inches = 1 meter (int.).
- 1 **ell** [E, e] (cloth; Brit.) = 45. inches = 1.143 0 meters.
- 1 **fathom** (U. S.) = 6. feet = 1.828 8 (aprx. $\frac{9}{10}$) meters.
- 1 **fathom** (Brit.) = 6.080 feet = 1.853 2 (aprx. $\frac{11}{10}$) meters = $\frac{1}{1000}$ nautical mile (Brit.).
- 1 **rod** [r], **pole** [p], or **perch** [p] (surveyor's) = $5\frac{1}{2}$ yards = 5.029 2 meters.
- 1 **decameter** or **dekameter** [dkm] = 10. meters.
- 1 **chain** [ch] (Gunter's or surveyor's) = 100. links (surveyor's) = 66. feet = 20.117 meters = 4. rods, poles, or perches = $\frac{1}{10}$ furlong = $\frac{1}{80}$ mile.
- 1 **chain** [ch] (engineer's) = 100. links (engineer's) = 100. feet = 30.480 meters.
- 1 **chain** [ch] (Philadelphia standard) = 100 $\frac{1}{4}$ feet = 30.556 meters.
- 1 **bolt** (cloth) = 40. yards.
- 1 **hectometer** = 100. meters.
- 1 **furlong** [fur] = 660. feet = 201.17 meters = 40. rods, poles, or perches = 10. chains (Gunter's or surveyor's) = $\frac{1}{8}$ mile.
- 1 **cable** or **cable's length** (Brit. navy) = 608. feet (sometimes stated as 608.6 feet) = $\frac{1}{10}$ nautical mile (Brit.).
- 1 **cable's length** (U. S. Navy) = 720. feet = 219.457 meters = 120. fathoms (U. S.).
- 1 **car-mile**, see under units of Energy.
- 1 **knot** (telegraph; Brit.) = 2 029. yards = 1 855.32 meters.
- 1 **geographical mile**, sometimes used for nautical mile; see also under international geographical mile.
- 1 **international nautical or sea mile** = 6 076.10 feet = 1 852. meters = $\frac{1}{60}$ of 1° of meridian.
- 1° of **latitude** at equator = 60. (aprx.) nautical miles.
 " " " " " " = 68.70 miles (statute).
 " " " " " lat. 20° = 68.78 " "
 " " " " " " 40° = 69.00 " "
 " " " " " " 60° = 69.23 " "
 " " " " " " 80° = 69.39 " "
 " " " " " " 90° = 69.41 " "
- 1° of **longitude** at equator = 60. (aprx.) nautical miles.
 " " " " " " = 69.16 miles (statute).
 " " " " " lat. 20° = 65.02 " "
 " " " " " " 40° = 53.05 " "
 " " " " " " 60° = 34.67 " "
 " " " " " " 80° = 12.05 " "
- 1 **legua** (California; legal) = 2.633 5 miles = 5 000. varas.
- 1 **league** (U. S.) = 4.828 05 kilometers = 3. miles (statute); also given as 3. nautical miles.
- 1 **international geographical mile** = 24 350.3 feet = 7 422. meters = 4.611 80 miles (statute) = 4. (aprx.) nautical miles = $\frac{1}{15}$ of 1° at equator. The term geographical mile is sometimes used also for nautical mile.
- 1 **myriameter** or **miriameter** = 10. kilometers.
- 1 **mean diameter of the earth** ‡ (astronomy) = 12 742.0 kilometers = 7 917.5 miles.
- 1 **mean diameter of earth's orbit** § (astronomy) = 149 340 870 ± 93 101 kilometers = 92 796 950 ± 59 715 miles.

† Michelson; cadmium light waves for air at 15° C. and a pressure of 760 mm. mercury.

‡ Based on the accepted value of a nautical mile as defined above.

§ Harkness.

LENGTHS (concluded). Foreign.

These are mostly obsolete, as the metric system is now used in most foreign countries. The British measures are included among the U. S. measures, being very nearly, and sometimes quite the same. The translated terms are merely synonymous, and not the exact equivalents.

Germany. Prussia. Legal May 16, 1816. 1 Fuss ['] (foot)=12 Zoll ["] (inches) of 12 Linien [''''] (lines). 1 Fuss (also called "rheinlaendischer Fuss," that is, Rhineland foot)=0.313 853 5 meter. Road measure: 1 Meile (mile)=2 000 Ruthen (rods) of 12 Fuss (feet); 1 Meile=7.532 5 kilometers; 1 Ruthe=3.766 25 meters. From Jan. 1, 1872, to Jan. 1, 1874: 1 deutsche Meile (German mile)=7.500 kilometers. Trade measure: 1 Elle (yard)=2½ Fuss (feet)=25½ Zoll (inch)=0.666 939 meter. 1 Lachter=80 Zoll (inches)=2.092 36 meters.

Bavaria. 1 Fuss (foot)=12 Zoll (inches) of 12 Linien (lines). More rarely 1 Fuss=10 Zoll of 10 Linien. 1 Fuss=0.291 859 meter.

Saxony. 1 Fuss=0.283 19 meter; subdivisions like in Bavaria.

Wuerttemberg. 1 Fuss=0.286 49 meter; subdivisions like in Baden.

Baden. 1 Fuss (foot)=10 Zoll (inches) of 10 Linien (lines). 1 Fuss=0.3 meter.

Hanover. 1 Fuss=0.292 1 meter.

The following values of various German feet in inches are given in Nystrom's Mechanics: Bavaria, 11.42; Berlin, 12.19; Bremen, 11.38; Dresden, 11.14; Hamburg, 11.29; Hanover, 11.45; Leipsic, 11.11; Prussia, 12.36; Rhineland, 12.35; Strasburg, 11.39. Also the following road measures: Germany, mile, long, 10 126 yards; Hamburg mile, 8 244 yards; Hanover mile, 11 559 yards; Prussia mile, 8 468 yards.

France. "Old measures" (système ancien) used prior to 1812: 1 toise (fathom)=6 pieds (du roi) (feet) of 12 pouces (inches) of 12 lignes (lines) of 12 points. In geodesy: 1 pied=10 pouces of 10 lignes of 10 points. 1 toise=1.949 037 meters. Road measure: 1 lieue (league)=2 283 toises=4 449.65 meters; 1 lieue marine=2 854 toises=5 562.55 meters; 1 lieue moyenne=2 534 toises=4 938.86 meters. Field measure: 1 perche (perch)=18 or 22 pieds. For depths of the sea: 1 brasse=5 pieds. Trade: 1 aune (yard) de Paris=1.188 45 meters. According to Nystrom's Mechanics: 1 pied du roi=12.79 inches; 1 league (lieue) marine=6 075 yards; 1 league, common=4 861 yards; 1 league, post,=4 264 yards.

"Usual" measures (système usuel) used from 1812 to 1840: 1 toise (fathom)=2 meters; 1 pied (foot)=½ meter; 1 aune (yard)=1.2 meters. For subdivisions into other units see above under "old measures." 1 noeud =1 knot or nautical mile.

Austria. 1 Ruthe (rod)=10 Fuss (feet) of 12 Zoll (inches) of 12 Linien (lines). 1 Fuss=0.316 10 meter. 1 Meile (mile)=7.586 kilometers=4 000 Klafter of 6 Fuss. 1 Elle (yard)=2.46 Fuss. According to Nystrom's Mechanics: 1 Vienna foot=12.45 inches.

Sweden. 1 meile (mile)=6 000 famn of 3 alnar of 2 fot (foot) of 10 tum (inches) (or 12 vorktum) of 10 linier (lines). 1 meile=10.688 4 kilometers. 1 fot=0.296 901 meter. 1 ruthe (rod)=16 fot. 1 corde=10 stangen of 10 fot. According to Nystrom's Mechanics: 1 Swedish foot=11.69 inches; 1 Swedish mile=11 700. yards.

Russia. 1 werst=500 sashchn of 3 arschin of 4 tschetwert of 4 werschock. 1 werst=1.066 8 kilometers=3 500 feet=0.662 88 mile. 1 sashchn=2.133 6 meters=7.0 feet (U. S.). 1 arschin=71.12 centimeters=28.0 inches. 1 tschetwert=17.780 centimeters=7.0 inches. 1 werschock=4.445 centimeters=1.75 inches. The British foot is also used; 1 foot=12 inches of 12 lines. According to Nystrom's Mechanics: 1 Russian foot=13.75 inches; 1 Moscow foot=13.17 inches; 1 Riga foot=10.79 inches; 1 Warsaw foot=14.03 inches; 1 werst=1 167. yards.

Switzerland. 1 Fuss (foot)=10 Zoll (inches) of 10 Linien (lines). 1 Fuss=0.3 meter. According to Nystrom's Mechanics: 1 Geneva foot=19.20 inches; 1 Zurich foot=11.81 inches; 1 Swiss mile=9 153 yards.

Holland. 1 Ruthe (rod)=12 Fuss (feet). 1 Ruthe=3.767 36 meters; 1 Fuss=0.313 947 meter. According to Nystrom's Mechanics: 1 Amsterdam foot=11.14 inches; 1 Utrecht foot=10.74 inches; 1 Flanders mile=

6 869 yards; 1 Holland mile=6 395 yards; 1 Netherlands mile=1 093 yards.

Spain. 1 vara (yard)=32.874 8 inches=0.835 022 meter. According to Nystrom's Mechanics: 1 Spanish foot=11.03 inches; 1 toesas=66.72 inches; 1 palmo=8.64 inches; 1 Spanish common league=7 416 yards.

Italy. According to Nystrom's Mechanics: 1 Florence braccio=21.69 inches; 1 Genoa palmo=9.72 inches; 1 Malta foot=11.17 inches; 1 Naples palmo=10.38 inches; 1 Rome foot=11.60 inches; 1 Sardinia palmo=9.78 inches; 1 Sicily palmo=9.53 inches; 1 Turin foot=12.72 inches; 1 Venice foot=13.40 inches; 1 Rome mile=2 025. yards.

Japan. Long measure: 1 ri=36 cho of 60 ken of 6 shaku of 10 sun of 10 bu. 1 jo=10 shaku. 1 ri=3.93 kilometers=2.44 miles. 1 kilometer=0.255 ri. 1 mile=0.410 ri. For cloth measure: 1 jo=10 shaku of 10 sun of 10 bu; the unit is the jo; in this measure the units are $\frac{1}{4}$ longer than those of the same name in the long measure.

Miscellaneous (from Nystrom's Mechanics): Antwerp foot=11.24 inches; Brussels foot=11.45 inches. Denmark mile=8 244 yards; Copenhagen foot=12.35 inches. Portugal league=6 760 yards; Lisbon foot=12.96 inches; Lisbon palmo=8.64 inches. Ireland mile=3 038 yards; Scotland mile=1 984 yards. Hungary mile=9 113 yards. Bohemia mile=10 137 yards. Poland mile, long.=8 101 yards. Turkey berri=1 826 yards. Persia parasang=6 086 yards; Persia arish=38.27 inches. Arabia mile=2 148 yards. China li=629 yards; mathematic foot=13.12 inches; builder's foot=12.71 inches; tradesman's foot=13.32 inches; surveyor's foot=12.58 inches.

Ancient. Biblical: 1 digit=0.912 inch; 1 palm=4 digits=3.648 inches; 1 span=3 palms=10.94 inches; 1 cubit=2 spans=21.888 inches; 1 fathom=3.46 cubits=7.296 feet. Egyptian: 1 finger=0.737 4 inch; 1 nahud cubit=1.476 feet; 1 royal cubit=1.722 feet. Grecian: 1 digit=0.754 inch; 1 pous=16 digits=1.007 3 feet; 1 cubit=1.133 feet; 1 stadium=604.375 feet; 1 mile=8 stadiums=4 835. feet. Hebrew: 1 cubit=1.822 feet; 1 Sabbath day's journey=3 648. feet; 1 mile=4 000 cubits=7 296 feet; 1 day's journey=33.164 miles; 1 sacred cubit=2.02 feet. Roman: 1 digit=0.725 7 inch; 1 uncia (inch)=0.967 inch; 1 pes (foot)=12 uncias=11.60 inches; 1 cubit=24 digits=1.45 feet; 1 passus=3.33 cubits=4.835 feet; 1 millarium (mile)=4 842 feet. Arabian: 1 foot=1.095 feet. Babylonian: 1 foot=1.14 feet.

Lengths in which Overhead Telegraph Lines Are or Were Expressed in Different Countries. (From Munro and Jamieson's Pocket Book.) The lengths here given are in English or statute miles of 5 280 feet. Arabia, mile 1.220 4. Austria, mile 5.753 4. Bohemia, mile 5.759 6. Brabant, league 3.452 2. Burgundy, league 2.516 6. China, li 0.359 1. Denmark, mile 4.684 1. Flanders, league 3.90. Hamburg, mile 4.684 1. Hanover, mile 6.567 6. Hesse, mile 5.992 6. Holland, mile 4.602 8. Hungary, mile 5.177 8. Italy, mile 1.150 5. Lithuania, mile 5.557 3. Norway, mile 7.018 3. Oldenburg, mile 6.147 7. Poland, long mile 4.602 8; short mile 3.451 7. Portugal, league 3.840 9. Prussia, mile 4.806 8; Rome, mile 0.925 0. Russia, verst 0.663 0. Saxony, mile 5.627 8. Silesia, mile 4.024 4. Spain, common legua of 8 000. varas, 4.213 6; legal legua of 5 000 veras, 2.753 4. Swabia, mile 5.633 5. Sweden, mile 6.647 7. Switzerland, mile 5.200 5. Turkey, berri 1.037 5. Tuscany, mile 1.027 2. Westphalia, mile 6.903 9.

Inches in Fractions, Decimals, Millimeters, and Feet.

For every 64th of an inch up to 1 inch; for every 32d of an inch up to 6 inches; for every 16th of an inch up to 12 inches; for every inch up to 10 feet. The equivalents of other intermediate values, or of values beyond the table, may be found by adding together two or more values from the table; thus for $11\frac{3}{32}$ inches add that for 11 inches to that for $\frac{3}{32}$.

Milli- meters.	Inches.		Feet.	Milli- meters.	Inches.		Feet.
0.396 876	$\frac{1}{64}$	0.015 625	0.001 302	19.446 9	$49\frac{1}{64}$	0.765 625	0.063 80
0.793 752	$\frac{1}{32}$	0.031 250	0.002 604	19.843 8	$25\frac{1}{32}$	0.781 250	0.065 10
1.190 63	$\frac{3}{64}$	0.046 875	0.003 906	20.240 7	$51\frac{1}{64}$	0.796 875	0.066 41
1.587 50	$\frac{1}{16}$	0.062 500	0.005 208	20.637 5	$13\frac{1}{16}$	0.812 500	0.067 71
1.984 38	$\frac{5}{64}$	0.078 125	0.006 510	21.034 4	$53\frac{1}{64}$	0.828 125	0.069 01
2.381 25	$\frac{3}{32}$	0.093 750	0.007 813	21.431 3	$27\frac{1}{32}$	0.843 750	0.070 31
2.778 13	$\frac{7}{64}$	0.109 375	0.009 115	21.828 2	$55\frac{1}{64}$	0.859 375	0.071 61
3.175 01	$\frac{1}{8}$	0.125 000	0.010 42	22.225 0	$\frac{7}{8}$	0.875 000	0.072 92
3.571 88	$\frac{9}{64}$	0.140 625	0.011 72	22.621 9	$57\frac{1}{64}$	0.890 625	0.074 22
3.968 76	$\frac{5}{32}$	0.156 250	0.013 02	23.018 8	$29\frac{1}{32}$	0.906 250	0.075 52
4.365 63	$1\frac{1}{64}$	0.171 875	0.014 32	23.415 7	$59\frac{1}{64}$	0.921 875	0.076 82
4.762 51	$\frac{3}{16}$	0.187 500	0.015 63	23.812 5	$15\frac{1}{16}$	0.937 500	0.078 13
5.159 39	$13\frac{1}{64}$	0.203 125	0.016 93	24.209 4	$61\frac{1}{64}$	0.953 125	0.079 43
5.556 26	$\frac{7}{32}$	0.218 750	0.018 23	24.606 3	$3\frac{1}{32}$	0.968 750	0.080 73
5.953 14	$15\frac{1}{64}$	0.234 375	0.019 53	25.003 2	$63\frac{1}{64}$	0.984 375	0.082 03
6.350 01	$\frac{1}{4}$	0.250 000	0.020 83	25.400 1	1	1.000 000	0.083 33
6.746 89	$17\frac{1}{64}$	0.265 625	0.022 14	26.193 8	$11\frac{1}{32}$	1.031 250	0.085 94
7.143 76	$\frac{9}{32}$	0.281 250	0.023 44	26.987 6	$11\frac{1}{16}$	1.062 500	0.088 54
7.540 64	$19\frac{1}{64}$	0.296 875	0.024 74	27.781 3	$13\frac{1}{32}$	1.093 750	0.091 15
7.937 52	$\frac{5}{16}$	0.312 500	0.026 04	28.575 1	$11\frac{1}{8}$	1.125 000	0.093 75
8.334 39	$21\frac{1}{64}$	0.328 125	0.027 34	29.368 8	$15\frac{1}{32}$	1.156 250	0.096 35
8.731 27	$11\frac{1}{32}$	0.343 750	0.028 65	30.162 6	$13\frac{1}{16}$	1.187 500	0.098 96
9.128 14	$23\frac{1}{64}$	0.359 375	0.029 95	30.956 3	$17\frac{1}{32}$	1.218 750	0.101 6
9.525 02	$\frac{3}{8}$	0.375 000	0.031 25	31.750 1	$11\frac{1}{4}$	1.250 000	0.104 2
9.921 89	$25\frac{1}{64}$	0.390 625	0.032 55	32.543 8	$19\frac{1}{32}$	1.281 250	0.106 8
10.318 8	$13\frac{1}{32}$	0.406 250	0.033 85	33.337 6	$15\frac{1}{16}$	1.312 500	0.109 4
10.715 6	$27\frac{1}{64}$	0.421 875	0.035 16	34.131 3	$11\frac{1}{16}$	1.343 750	0.112 0
11.112 5	$\frac{7}{16}$	0.437 500	0.036 46	34.925 1	$13\frac{1}{8}$	1.375 000	0.114 6
11.509 4	$29\frac{1}{64}$	0.453 125	0.037 76	35.718 8	$11\frac{1}{32}$	1.406 250	0.117 2
11.906 3	$15\frac{1}{32}$	0.468 750	0.039 06	36.512 6	$17\frac{1}{16}$	1.437 500	0.119 8
12.303 1	$31\frac{1}{64}$	0.484 375	0.040 36	37.306 3	$11\frac{1}{32}$	1.468 750	0.122 4
12.700 0	$\frac{1}{2}$	0.500 000	0.041 67	38.100 1	$11\frac{1}{2}$	1.500 000	0.125 0
13.096 9	$33\frac{1}{64}$	0.515 625	0.042 97	38.893 8	$117\frac{1}{32}$	1.531 250	0.127 6
13.493 8	$17\frac{1}{32}$	0.531 250	0.044 27	39.687 6	$19\frac{1}{16}$	1.562 500	0.130 2
13.890 7	$35\frac{1}{64}$	0.546 875	0.045 57	40.481 3	$119\frac{1}{32}$	1.593 750	0.132 8
14.287 5	$\frac{9}{16}$	0.562 500	0.046 88	41.275 1	$15\frac{1}{8}$	1.625 000	0.135 4
14.684 4	$37\frac{1}{64}$	0.578 125	0.048 18	42.068 8	$121\frac{1}{32}$	1.656 250	0.138 0
15.081 3	$19\frac{1}{32}$	0.593 750	0.049 48	42.862 6	$111\frac{1}{16}$	1.687 500	0.140 6
15.478 2	$39\frac{1}{64}$	0.609 375	0.050 78	43.656 3	$123\frac{1}{32}$	1.718 750	0.143 2
15.875 0	$\frac{5}{8}$	0.625 000	0.052 08	44.450 1	$13\frac{1}{4}$	1.750 000	0.145 8
16.271 9	$41\frac{1}{64}$	0.640 625	0.053 39	45.243 8	$125\frac{1}{32}$	1.781 250	0.148 4
16.668 8	$21\frac{1}{32}$	0.656 250	0.054 69	46.037 6	$113\frac{1}{16}$	1.812 500	0.151 0
17.065 7	$43\frac{1}{64}$	0.671 875	0.055 99	46.831 3	$127\frac{1}{32}$	1.843 750	0.153 6
17.462 5	$11\frac{1}{16}$	0.687 500	0.057 29	47.625 1	$17\frac{1}{8}$	1.875 000	0.156 3
17.859 4	$45\frac{1}{64}$	0.703 125	0.058 59	48.418 8	$129\frac{1}{32}$	1.906 250	0.158 9
18.256 3	$23\frac{1}{32}$	0.718 750	0.059 90	49.212 6	$115\frac{1}{16}$	1.937 500	0.161 5
18.653 2	$47\frac{1}{64}$	0.734 375	0.061 20	50.006 3	$131\frac{1}{32}$	1.968 750	0.164 1
19.050 0	$\frac{3}{4}$	0.750 000	0.062 50	50.800 1	2	2.000 000	0.166 7

Milli- meters.	Inches.		Feet.	Milli- meters.	Inches.		Feet.
51.593 9	$2\frac{1}{32}$	2.031 250	0.169 3	96.043 9	$3\frac{25}{32}$	3.781 250	0.315 1
52.387 6	$2\frac{1}{16}$	2.062 500	0.171 9	96.837 7	$3\frac{13}{16}$	3.812 500	0.317 7
53.181 4	$2\frac{3}{32}$	2.093 750	0.174 5	97.631 4	$3\frac{27}{32}$	3.843 750	0.320 3
53.975 1	$2\frac{1}{8}$	2.125 000	0.177 1	98.425 2	$3\frac{7}{8}$	3.875 000	0.322 9
54.768 9	$2\frac{5}{32}$	2.156 250	0.179 7	99.218 9	$3\frac{29}{32}$	3.906 250	0.325 5
55.562 6	$2\frac{3}{16}$	2.187 500	0.182 3	100.013	$3\frac{15}{16}$	3.937 500	0.328 1
56.356 4	$2\frac{7}{32}$	2.218 750	0.184 9	100.806	$3\frac{31}{32}$	3.968 750	0.330 7
57.150 1	$2\frac{1}{4}$	2.250 000	0.187 5	101.600	4	4.000 000	0.333 3
57.943 9	$2\frac{9}{32}$	2.281 250	0.190 1	102.394	$4\frac{1}{32}$	4.031 250	0.335 9
58.737 6	$2\frac{5}{16}$	2.312 500	0.192 7	103.188	$4\frac{1}{16}$	4.062 500	0.338 5
59.531 4	$2\frac{11}{32}$	2.343 750	0.195 3	103.981	$4\frac{3}{8}$	4.093 750	0.341 1
60.325 1	$2\frac{3}{8}$	2.375 000	0.197 9	104.775	$4\frac{1}{8}$	4.125 000	0.343 8
61.118 9	$2\frac{13}{32}$	2.406 250	0.200 5	105.569	$4\frac{5}{32}$	4.156 250	0.346 4
61.912 6	$2\frac{7}{16}$	2.437 500	0.203 1	106.363	$4\frac{3}{16}$	4.187 500	0.349 0
62.706 4	$2\frac{15}{32}$	2.468 750	0.205 7	107.156	$4\frac{7}{32}$	4.218 750	0.351 6
63.500 1	$2\frac{1}{2}$	2.500 000	0.208 3	107.950	$4\frac{1}{4}$	4.250 000	0.354 2
64.293 9	$2\frac{17}{32}$	2.531 250	0.210 9	108.744	$4\frac{9}{32}$	4.281 250	0.356 8
65.087 6	$2\frac{9}{16}$	2.562 500	0.213 5	109.538	$4\frac{5}{16}$	4.312 500	0.359 4
65.881 4	$2\frac{19}{32}$	2.593 750	0.216 1	110.331	$4\frac{11}{32}$	4.343 750	0.362 0
66.675 1	$2\frac{5}{8}$	2.625 000	0.218 8	111.125	$4\frac{3}{8}$	4.375 000	0.364 6
67.468 9	$2\frac{21}{32}$	2.656 250	0.221 4	111.919	$4\frac{13}{32}$	4.406 250	0.367 2
68.262 6	$2\frac{11}{16}$	2.687 500	0.224 0	112.713	$4\frac{7}{16}$	4.437 500	0.369 8
69.056 4	$2\frac{23}{32}$	2.718 750	0.226 6	113.506	$4\frac{15}{32}$	4.468 750	0.372 4
69.850 1	$2\frac{3}{4}$	2.750 000	0.229 2	114.300	$4\frac{1}{2}$	4.500 000	0.375 0
70.643 9	$2\frac{25}{32}$	2.781 250	0.231 8	115.094	$4\frac{17}{32}$	4.531 250	0.377 6
71.437 6	$2\frac{13}{16}$	2.812 500	0.234 4	115.888	$4\frac{9}{16}$	4.562 500	0.380 2
72.231 4	$2\frac{27}{32}$	2.843 750	0.237 0	116.681	$4\frac{19}{32}$	4.593 750	0.382 8
73.025 1	$2\frac{7}{8}$	2.875 000	0.239 6	117.475	$4\frac{5}{8}$	4.625 000	0.385 4
73.818 9	$2\frac{29}{32}$	2.906 250	0.242 2	118.269	$4\frac{21}{32}$	4.656 250	0.388 0
74.612 7	$2\frac{15}{16}$	2.937 500	0.244 8	119.063	$4\frac{11}{16}$	4.687 500	0.390 6
75.406 4	$2\frac{31}{32}$	2.968 750	0.247 4	119.856	$4\frac{23}{32}$	4.718 750	0.393 2
76.200 2	3	3.000 000	0.250 0	120.650	$4\frac{3}{4}$	4.750 000	0.395 8
76.993 9	$3\frac{1}{32}$	3.031 250	0.252 6	121.444	$4\frac{25}{32}$	4.781 250	0.398 4
77.787 7	$3\frac{1}{16}$	3.062 500	0.255 2	122.238	$4\frac{13}{16}$	4.812 500	0.401 0
78.581 4	$3\frac{3}{32}$	3.093 750	0.257 8	123.031	$4\frac{27}{32}$	4.843 750	0.403 6
79.375 2	$3\frac{1}{8}$	3.125 000	0.260 4	123.825	$4\frac{7}{8}$	4.875 000	0.406 3
80.168 9	$3\frac{5}{32}$	3.156 250	0.263 0	124.619	$4\frac{29}{32}$	4.906 250	0.408 9
80.962 7	$3\frac{3}{16}$	3.187 500	0.265 6	125.413	$4\frac{15}{16}$	4.937 500	0.411 5
81.756 4	$3\frac{7}{32}$	3.218 750	0.268 2	126.207	$4\frac{31}{32}$	4.968 750	0.414 1
82.550 2	$3\frac{1}{4}$	3.250 000	0.270 8	127.000	5	5.000 000	0.416 7
83.343 9	$3\frac{9}{32}$	3.281 250	0.273 4	127.794	$5\frac{1}{32}$	5.031 250	0.419 3
84.137 7	$3\frac{5}{16}$	3.312 500	0.276 0	128.588	$5\frac{1}{16}$	5.062 500	0.421 9
84.931 4	$3\frac{11}{32}$	3.343 750	0.278 6	129.382	$5\frac{3}{8}$	5.093 750	0.424 5
85.725 2	$3\frac{3}{8}$	3.375 000	0.281 3	130.175	$5\frac{1}{8}$	5.125 000	0.427 1
86.518 9	$3\frac{13}{32}$	3.406 250	0.283 9	130.969	$5\frac{5}{32}$	5.156 250	0.429 7
87.312 7	$3\frac{7}{16}$	3.437 500	0.286 5	131.763	$5\frac{3}{16}$	5.187 500	0.432 3
88.106 4	$3\frac{15}{32}$	3.468 750	0.289 1	132.557	$5\frac{7}{32}$	5.218 750	0.434 9
88.900 2	$3\frac{1}{2}$	3.500 000	0.291 7	133.350	$5\frac{1}{4}$	5.250 000	0.437 5
89.693 9	$3\frac{17}{32}$	3.531 250	0.294 3	134.144	$5\frac{9}{32}$	5.281 250	0.440 1
90.487 7	$3\frac{9}{16}$	3.562 500	0.296 9	134.938	$5\frac{1}{16}$	5.312 500	0.442 7
91.281 4	$3\frac{19}{32}$	3.593 750	0.299 5	135.732	$5\frac{11}{32}$	5.343 750	0.445 3
92.075 2	$3\frac{5}{8}$	3.625 000	0.302 1	136.525	$5\frac{3}{8}$	5.375 000	0.447 9
92.868 9	$3\frac{21}{32}$	3.656 250	0.304 7	137.319	$5\frac{13}{32}$	5.406 250	0.450 5
93.662 7	$3\frac{11}{16}$	3.687 500	0.307 3	138.113	$5\frac{7}{16}$	5.437 500	0.453 1
94.456 4	$3\frac{23}{32}$	3.718 750	0.309 9	138.907	$5\frac{15}{32}$	5.468 750	0.455 7
95.250 2	$3\frac{3}{4}$	3.750 000	0.312 5	139.700	$5\frac{1}{2}$	5.500 000	0.458 3

Milli- meters.	Inches.		Feet.	Milli- meters.	Inches.		Feet.
140.494	$5\frac{17}{32}$	5.531 250	0.460 9	217.488	$8\frac{9}{16}$	8.562 500	0.713 5
141.288	$5\frac{9}{16}$	5.562 500	0.463 5	219.075	$8\frac{5}{8}$	8.625 000	0.718 8
142.082	$5\frac{19}{32}$	5.593 750	0.466 1	220.663	$8\frac{11}{16}$	8.687 500	0.724 0
142.875	$5\frac{5}{8}$	5.625 000	0.468 8	222.250	$8\frac{3}{4}$	8.750 000	0.729 2
143.669	$5\frac{21}{32}$	5.656 250	0.471 4	223.838	$8\frac{13}{16}$	8.812 500	0.734 4
144.463	$5\frac{11}{16}$	5.687 500	0.474 0	225.425	$8\frac{7}{8}$	8.875 000	0.739 6
145.257	$5\frac{23}{32}$	5.718 750	0.476 6	227.013	$8\frac{15}{16}$	8.937 500	0.744 8
146.050	$5\frac{3}{4}$	5.750 000	0.479 2	228.600	9	9.000 000	0.750 0
146.844	$5\frac{25}{32}$	5.781 250	0.481 8	230.188	$9\frac{1}{16}$	9.062 500	0.755 2
147.638	$5\frac{13}{16}$	5.812 500	0.484 4	231.775	$9\frac{1}{8}$	9.125 000	0.760 4
148.432	$5\frac{27}{32}$	5.843 750	0.487 0	233.363	$9\frac{3}{16}$	9.187 500	0.765 6
149.225	$5\frac{7}{8}$	5.875 000	0.489 6	234.950	$9\frac{1}{4}$	9.250 000	0.770 8
150.019	$5\frac{29}{32}$	5.906 250	0.492 2	236.538	$9\frac{5}{16}$	9.312 500	0.776 0
150.813	$5\frac{15}{16}$	5.937 500	0.494 8	238.125	$9\frac{3}{8}$	9.375 000	0.781 3
151.607	$5\frac{31}{32}$	5.968 750	0.497 4	239.713	$9\frac{7}{16}$	9.437 500	0.786 5
152.400	6	6.000 000	0.500 0	241.300	$9\frac{1}{2}$	9.500 000	0.791 7
153.988	$6\frac{1}{16}$	6.062 500	0.505 2	242.888	$9\frac{9}{16}$	9.562 500	0.796 9
155.575	$6\frac{1}{8}$	6.125 000	0.510 4	244.475	$9\frac{5}{8}$	9.625 000	0.802 1
157.163	$6\frac{3}{16}$	6.187 500	0.515 6	246.063	$9\frac{11}{16}$	9.687 500	0.807 3
158.750	$6\frac{1}{4}$	6.250 000	0.520 8	247.650	$9\frac{3}{4}$	9.750 000	0.812 5
160.338	$6\frac{5}{16}$	6.312 500	0.526 0	249.238	$9\frac{13}{16}$	9.812 500	0.817 7
161.925	$6\frac{3}{8}$	6.375 000	0.531 3	250.825	$9\frac{7}{8}$	9.875 000	0.822 9
163.513	$6\frac{7}{16}$	6.437 500	0.536 5	252.413	$9\frac{15}{16}$	9.937 500	0.828 1
165.100	$6\frac{1}{2}$	6.500 000	0.541 7	254.001	10	10.000 000	0.833 3
166.688	$6\frac{9}{16}$	6.562 500	0.546 9	255.588	$10\frac{1}{16}$	10.062 500	0.838 5
168.275	$6\frac{5}{8}$	6.625 000	0.552 1	257.176	$10\frac{1}{8}$	10.125 000	0.843 8
169.863	$6\frac{11}{16}$	6.687 500	0.557 3	258.763	$10\frac{3}{16}$	10.187 500	0.849 0
171.450	$6\frac{3}{4}$	6.750 000	0.562 5	260.351	$10\frac{1}{4}$	10.250 000	0.854 2
173.038	$6\frac{13}{16}$	6.812 500	0.567 7	261.938	$10\frac{5}{16}$	10.312 500	0.859 4
174.625	$6\frac{7}{8}$	6.875 000	0.572 9	263.526	$10\frac{3}{8}$	10.375 000	0.864 6
176.213	$6\frac{15}{16}$	6.937 500	0.578 1	265.113	$10\frac{7}{16}$	10.437 500	0.869 8
177.800	7	7.000 000	0.583 3	266.701	$10\frac{1}{2}$	10.500 000	0.875 0
179.388	$7\frac{1}{16}$	7.062 500	0.588 5	268.288	$10\frac{9}{16}$	10.562 500	0.880 2
180.975	$7\frac{1}{8}$	7.125 000	0.593 8	269.876	$10\frac{5}{8}$	10.625 000	0.885 4
182.563	$7\frac{3}{16}$	7.187 500	0.599 0	271.463	$10\frac{11}{16}$	10.687 500	0.890 6
184.150	$7\frac{1}{4}$	7.250 000	0.604 2	273.051	$10\frac{3}{4}$	10.750 000	0.895 8
185.738	$7\frac{5}{16}$	7.312 500	0.609 4	274.638	$10\frac{13}{16}$	10.812 500	0.901 0
187.325	$7\frac{3}{8}$	7.375 000	0.614 6	276.226	$10\frac{7}{8}$	10.875 000	0.906 3
188.913	$7\frac{7}{16}$	7.437 500	0.619 8	277.813	$10\frac{15}{16}$	10.937 500	0.911 5
190.500	$7\frac{1}{2}$	7.500 000	0.625 0	279.401	11	11.000 000	0.916 7
192.088	$7\frac{9}{16}$	7.562 500	0.630 2	280.988	$11\frac{1}{16}$	11.062 500	0.921 9
193.675	$7\frac{5}{8}$	7.625 000	0.635 4	282.576	$11\frac{1}{8}$	11.125 000	0.927 1
195.263	$7\frac{11}{16}$	7.687 500	0.640 6	284.163	$11\frac{3}{16}$	11.187 500	0.932 3
196.850	$7\frac{3}{4}$	7.750 000	0.645 8	285.751	$11\frac{1}{4}$	11.250 000	0.937 5
198.438	$7\frac{13}{16}$	7.812 500	0.651 0	287.338	$11\frac{5}{16}$	11.312 500	0.942 7
200.025	$7\frac{7}{8}$	7.875 000	0.656 3	288.926	$11\frac{3}{8}$	11.375 000	0.947 9
201.613	$7\frac{15}{16}$	7.937 500	0.661 5	290.513	$11\frac{7}{16}$	11.437 500	0.953 1
203.200	8	8.000 000	0.666 7	292.101	$11\frac{1}{2}$	11.500 000	0.958 3
204.788	$8\frac{1}{16}$	8.062 500	0.671 9	293.688	$11\frac{9}{16}$	11.562 500	0.963 5
206.375	$8\frac{1}{8}$	8.125 000	0.677 1	295.276	$11\frac{5}{8}$	11.625 000	0.968 8
207.963	$8\frac{3}{16}$	8.187 500	0.682 3	296.863	$11\frac{11}{16}$	11.687 500	0.974 0
209.550	$8\frac{1}{4}$	8.250 000	0.687 5	298.451	$11\frac{3}{4}$	11.750 000	0.979 2
211.138	$8\frac{5}{16}$	8.312 500	0.692 7	300.038	$11\frac{13}{16}$	11.812 500	0.984 4
212.725	$8\frac{3}{8}$	8.375 000	0.697 9	301.626	$11\frac{7}{8}$	11.875 000	0.989 6
214.313	$8\frac{7}{16}$	8.437 500	0.703 1	303.213	$11\frac{15}{16}$	11.937 500	0.994 8
215.900	$8\frac{1}{2}$	8.500 000	0.708 3	304.801	12	12.000 000	1.000 0

Millimeters	Feet and Inches.		Millimeters.	Feet and Inches.	
304.801	1 foot	0 inches	1 676.40	5 feet	6 inches
330.201	1	1	1 701.80	5	7
355.601	1	2	1 727.20	5	8
381.001	1	3	1 752.60	5	9
406.401	1	4	1 778.00	5	10
431.801	1	5	1 803.40	5	11
457.201	1	6	1 828.80	6	0
482.601	1	7	1 854.20	6	1
508.001	1	8	1 879.60	6	2
533.401	1	9	1 905.00	6	3
558.801	1	10	1 930.40	6	4
584.201	1	11	1 955.80	6	5
609.601	2 feet	0	1 981.20	6	6
635.001	2	1	2 006.60	6	7
660.401	2	2	2 032.00	6	8
685.801	2	3	2 057.40	6	9
711.201	2	4	2 082.80	6	10
736.601	2	5	2 108.20	6	11
762.002	2	6	2 133.60	7	0
787.402	2	7	2 159.00	7	1
812.802	2	8	2 184.40	7	2
838.202	2	9	2 209.80	7	3
863.602	2	10	2 235.20	7	4
889.002	2	11	2 260.60	7	5
914.402	3	0	2 286.00	7	6
939.802	3	1	2 311.40	7	7
965.202	3	2	2 336.80	7	8
990.602	3	3	2 362.20	7	9
1 016.00	3	4	2 387.60	7	10
1 041.40	3	5	2 413.00	7	11
1 066.80	3	6	2 438.40	8	0
1 092.20	3	7	2 463.80	8	1
1 117.60	3	8	2 489.20	8	2
1 143.00	3	9	2 514.61	8	3
1 168.40	3	10	2 540.01	8	4
1 193.80	3	11	2 565.41	8	5
1 219.20	4	0	2 590.81	8	6
1 244.60	4	1	2 616.21	8	7
1 270.00	4	2	2 641.61	8	8
1 295.40	4	3	2 667.01	8	9
1 320.80	4	4	2 692.41	8	10
1 346.20	4	5	2 717.81	8	11
1 371.60	4	6	2 743.21	9	0
1 397.00	4	7	2 768.61	9	1
1 422.40	4	8	2 794.01	9	2
1 447.80	4	9	2 819.41	9	3
1 473.20	4	10	2 844.81	9	4
1 498.60	4	11	2 870.21	9	5
1 524.00	5	0	2 895.61	9	6
1 549.40	5	1	2 921.01	9	7
1 574.80	5	2	2 946.41	9	8
1 600.20	5	3	2 971.81	9	9
1 625.60	5	4	2 997.21	9	10
1 651.00	5	5	3 022.61	9	11
			3 048.01	10 feet	0

Conversion Tables for Lengths.

Ins. =	milim't							
Mms =	.....	inches.						
Feet =	.....		meters.					
Mtrs =	.....			feet....	.....	yards.		
Yds. =	.....				meters.			
Miles =	.....						klmtrs.	
Klms =	.....							miles.
1	25.400 1	0.039 370	0.304 801	3.280 83	0.914 402	1.093 61	1.609 35	.621 370
2	50.800 1	0.078 740	0.609 601	6.561 67	1.828 80	2.187 22	3.218 69	1.242 74
3	76.200 2	0.118 110	0.914 402	9.842 50	2.743 21	3.280 83	4.828 04	1.864 11
4	101.600	0.157 480	1.219 20	13.123 3	3.657 61	4.374 44	6.437 39	2.485 48
5	127.000	0.196 850	1.524 00	16.404 2	4.572 01	5.468 06	8.046 73	3.106 85
6	152.400	0.236 220	1.828 80	19.685 0	5.486 41	6.561 67	9.656 08	3.728 22
7	177.800	0.275 590	2.133 60	22.965 8	6.400 81	7.655 28	11.265 4	4.349 59
8	203.200	0.314 960	2.438 40	26.246 7	7.315 21	8.748 89	12.874 8	4.970 96
9	228.600	0.354 330	2.743 21	29.527 5	8.229 62	9.842 50	14.484 1	5.592 33
10	254.001	0.393 700	3.048 01	32.808 3	9.144 02	10.936 1	16.093 5	6.213 70
11	279.401	0.433 070	3.352 81	36.089 2	10.058 4	12.029 7	17.702 8	6.835 07
12	304.801	0.472 440	3.657 61	39.370 0	10.972 8	13.123 3	19.312 2	7.456 44
13	330.201	0.511 810	3.962 41	42.650 8	11.887 2	14.216 9	20.921 5	8.077 81
14	355.601	0.551 180	4.267 21	45.931 7	12.801 6	15.310 6	22.530 9	8.699 18
15	381.001	0.590 550	4.572 01	49.212 5	13.716 0	16.404 2	24.140 2	9.320 55
16	406.401	0.629 920	4.876 81	52.493 3	14.630 4	17.497 8	25.749 6	9.941 92
17	431.801	0.669 290	5.181 61	55.774 2	15.544 8	18.591 4	27.358 9	10.563 3
18	457.201	0.708 660	5.486 41	59.055 0	16.459 2	19.685 0	28.968 2	11.184 7
19	482.601	0.748 030	5.791 21	62.335 8	17.373 6	20.778 6	30.577 6	11.806 0
20	508.001	0.787 400	6.096 01	65.616 7	18.288 0	21.872 2	32.186 9	12.427 4
21	533.401	0.826 770	6.400 81	68.897 5	19.202 4	22.965 8	33.796 3	13.048 8
22	558.801	0.866 140	6.705 61	72.178 3	20.116 8	24.059 4	35.405 6	13.670 1
23	584.201	0.905 510	7.010 41	75.459 2	21.031 2	25.153 1	37.015 0	14.291 5
24	609.601	0.944 880	7.315 21	78.740 0	21.945 6	26.246 7	38.624 3	14.912 9
25	635.001	0.984 250	7.620 02	82.020 8	22.860 0	27.340 3	40.233 7	15.534 2
26	660.401	1.023 62	7.924 82	85.301 7	23.774 4	28.433 9	41.843 0	16.155 6
27	685.801	1.062 99	8.229 62	88.582 5	24.688 9	29.527 5	43.452 4	16.777 0
28	711.201	1.102 36	8.534 42	91.863 3	25.603 3	30.621 1	45.061 7	17.398 4
29	736.601	1.141 73	8.839 22	95.144 2	26.517 7	31.714 7	46.671 1	18.019 7
30	762.002	1.181 10	9.144 02	98.425 0	27.432 1	32.808 3	48.280 4	18.641 1
31	787.402	1.220 47	9.448 82	101.706	28.346 5	33.901 9	49.889 8	19.262 5
32	812.802	1.259 84	9.753 62	104.987	29.260 9	34.995 6	51.499 1	19.883 8
33	838.202	1.299 21	10.058 4	108.268	30.175 3	36.089 2	53.108 5	20.505 2
34	863.602	1.338 58	10.363 2	111.548	31.089 7	37.182 8	54.717 8	21.126 6
35	889.002	1.377 95	10.668 0	114.829	32.004 1	38.276 4	56.327 2	21.747 9
36	914.402	1.417 32	10.972 8	118.110	32.918 5	39.370 0	57.936 5	22.369 3
37	939.802	1.456 69	11.277 6	121.391	33.832 9	40.463 6	59.545 8	22.990 7
38	965.202	1.496 06	11.582 4	124.672	34.747 3	41.557 2	61.155 2	23.612 1
39	990.602	1.535 43	11.887 2	127.953	35.661 7	42.650 8	62.764 5	24.233 4
40	1 016.00	1.574 80	12.192 0	131.233	36.576 1	43.744 4	64.373 9	24.854 8
41	1 041.40	1.614 17	12.496 8	134.514	37.490 5	44.838 1	65.983 2	25.476 2
42	1 066.80	1.653 54	12.801 6	137.795	38.404 9	45.931 7	67.592 6	26.097 5
43	1 092.20	1.692 91	13.106 4	141.076	39.319 3	47.025 3	69.201 9	26.718 9
44	1 117.60	1.732 28	13.411 2	144.357	40.233 7	48.118 9	70.811 3	27.340 3
45	1 143.00	1.771 65	13.716 0	147.638	41.148 1	49.212 5	72.420 6	27.961 6
46	1 168.40	1.811 02	14.020 8	150.918	42.062 5	50.306 1	74.030 0	28.583 0
47	1 193.80	1.850 39	14.325 6	154.199	42.976 9	51.399 7	75.639 3	29.204 4
48	1 219.20	1.889 76	14.630 4	157.480	43.891 3	52.493 3	77.248 7	29.825 8
49	1 244.60	1.929 13	14.935 2	160.761	44.805 7	53.586 9	78.858 0	30.447 1
50	1 270.00	1.968 50	15.240 0	164.042	45.720 1	54.680 6	80.467 4	31.068 5

Conversion Tables for Lengths (CONCLUDED).

Ins. =	milim't							
Mms =	.....	inches.						
Feet =	.....		meters.					
Mtrs =	.....			feet.....	.....	yards.		
Yds. =	.....				meters.			
Miles =	.....					.....	klmtrs.	
Klms =	.....						.....	miles.
51	1 295.40	2.007 87	15.544 8	167.323	46.634 5	55.774 2	82.076 7	31.689 9
52	1 320.80	2.047 24	15.849 6	170.603	47.548 9	56.867 8	83.686 1	32.311 2
53	1 346.20	2.086 61	16.154 4	173.884	48.463 3	57.961 4	85.295 4	32.932 6
54	1 371.60	2.125 98	16.459 2	177.165	49.377 7	59.055 0	86.904 7	33.554 0
55	1 397.00	2.165 35	16.764 0	180.446	50.292 1	60.148 6	88.514 1	34.175 3
56	1 422.40	2.204 72	17.068 8	183.727	51.206 5	61.242 2	90.123 4	34.796 7
57	1 447.80	2.244 09	17.373 6	187.008	52.120 9	62.335 8	91.732 8	35.418 1
58	1 473.20	2.283 46	17.678 4	190.288	53.035 3	63.429 4	93.342 1	36.039 5
59	1 498.60	2.322 83	17.983 2	193.569	53.949 7	64.523 1	94.951 5	36.660 8
60	1 524.00	2.362 20	18.288 0	196.850	54.864 1	65.616 7	96.560 8	37.282 2
61	1 549.40	2.401 57	18.592 8	200.131	55.778 5	66.710 3	98.170 2	37.903 6
62	1 574.80	2.440 94	18.897 6	203.412	56.692 9	67.803 9	99.779 5	38.524 9
63	1 600.20	2.480 31	19.202 4	206.693	57.607 3	68.897 5	101.389	39.146 3
64	1 625.60	2.519 68	19.507 2	209.973	58.521 7	69.991 1	102.998	39.767 7
65	1 651.00	2.559 05	19.812 0	213.254	59.436 1	71.084 7	104.608	40.389 0
66	1 676.40	2.598 42	20.116 8	216.535	60.350 5	72.178 3	106.217	41.010 4
67	1 701.80	2.637 79	20.421 6	219.816	61.264 9	73.271 9	107.826	41.631 8
68	1 727.20	2.677 16	20.726 4	223.097	62.179 3	74.365 6	109.436	42.253 2
69	1 752.60	2.716 53	21.031 2	226.378	63.093 7	75.459 2	111.045	42.874 5
70	1 778.00	2.755 90	21.336 0	229.658	64.008 1	76.552 8	112.654	43.495 9
71	1 803.40	2.795 27	21.640 8	232.939	64.922 5	77.646 4	114.264	44.117 3
72	1 828.80	2.834 64	21.945 6	236.220	65.836 9	78.740 0	115.873	44.738 6
73	1 854.20	2.874 01	22.250 4	239.501	66.751 3	79.833 6	117.482	45.360 0
74	1 879.60	2.913 38	22.555 2	242.782	67.665 7	80.927 2	119.092	45.981 4
75	1 905.00	2.952 75	22.860 0	246.063	68.580 1	82.020 8	120.701	46.602 7
76	1 930.40	2.992 12	23.164 8	249.343	69.494 5	83.114 4	122.310	47.224 1
77	1 955.80	3.031 49	23.469 6	252.624	70.408 9	84.208 1	123.920	47.845 5
78	1 981.20	3.070 86	23.774 4	255.905	71.323 3	85.301 7	125.529	48.466 9
79	2 006.60	3.110 23	24.079 2	259.186	72.237 7	86.395 3	127.138	49.088 2
80	2 032.00	3.149 60	24.384 0	262.467	73.152 1	87.488 9	128.748	49.709 6
81	2 057.40	3.188 97	24.688 8	265.748	74.066 5	88.582 5	130.357	50.331 0
82	2 082.80	3.228 34	24.993 6	269.028	74.981 0	89.676 1	131.966	50.952 3
83	2 108.20	3.267 71	25.298 4	272.309	75.895 4	90.769 7	133.576	51.573 7
84	2 133.60	3.307 08	25.603 3	275.590	76.809 8	91.863 3	135.185	52.195 1
85	2 159.00	3.346 45	25.908 1	278.871	77.724 2	92.956 9	136.795	52.816 4
86	2 184.40	3.385 82	26.212 9	282.152	78.638 6	94.050 6	138.404	53.437 8
87	2 209.80	3.425 19	26.517 7	285.433	79.553 0	95.144 2	140.013	54.059 2
88	2 235.20	3.464 56	26.822 5	288.713	80.467 4	96.237 8	141.623	54.680 6
89	2 260.60	3.503 93	27.127 3	291.994	81.381 8	97.331 4	143.232	55.301 9
90	2 286.00	3.543 30	27.432 1	295.275	82.296 2	98.425 0	144.841	55.923 3
91	2 311.40	3.582 67	27.736 9	298.556	83.210 6	99.518 6	146.451	56.544 7
92	2 336.80	3.622 04	28.041 7	301.837	84.125 0	100.612	148.060	57.166 0
93	2 362.20	3.661 41	28.346 5	305.118	85.039 4	101.706	149.669	57.787 4
94	2 387.60	3.700 78	28.651 3	308.398	85.953 8	102.799	151.279	58.408 8
95	2 413.00	3.740 15	28.956 1	311.679	86.868 2	103.893	152.888	59.030 1
96	2 438.40	3.779 52	29.260 9	314.960	87.782 6	104.987	154.497	59.651 5
97	2 463.80	3.818 89	29.565 7	318.241	88.697 0	106.080	156.107	60.272 9
98	2 489.20	3.858 26	29.870 5	321.522	89.611 4	107.174	157.716	60.894 3
99	2 514.60	3.897 63	30.175 3	324.803	90.525 8	108.268	159.325	61.515 6
100	2 540.01	3.937 00	30.480 1	328.083	91.440 2	109.361	160.935	62.137 0

SURFACES.

There are no fundamental standards of surfaces or areas, as these measures are all based on the linear measures, which see for their fundamental values. The legal U. S. yard, foot, inch, mile, etc., being about 3 parts in one million larger than the legal values in Great Britain, the U. S. square yard, square foot, etc., will be about 6 parts in one million larger than the British, a difference which is absolutely negligible in all but the most refined physical measurements. The values given in the following tables are based on the U. S. legal relation. To reduce the values in these tables to British square miles, square yards, square feet, and similar units, when very great accuracy is required subtract 6 parts for every million from all those values of a sq. mile, sq. yard, etc., which are in terms of *other* units than miles, yards, etc.; for instance, add this correction in the value of one sq. mile in sq. meters, but not in sq. feet, as the latter is the same for both; or add 6 parts for every million to all the values of *other* units which are given in terms of sq. miles, sq. yards, etc. This will never affect the 5th place of figures by more than one unit and generally less.

A **circular unit** or measure (such as a circular mil) is the area of a circle whose diameter is one unit or measure (as one mil). It is used for cross-sections of round wires, pipes, rods, etc., and avoids the necessity of using the value of π ($=3.141\ 592\ 65$). If the diameter of a circle is d , its area in *circular units* is simply d^2 . Some of the specific relations given in the table may also be expressed as follows:

If d is the diameter of a circle expressed in one kind of a unit, then the area in the other unit will be:

if d is in mils the area in sq. millimeters	$=d^2 \times 0.000\ 506\ 709^*$
if d is in millimeters the area in sq. mils	$=d^2 \times 1\ 217.36^*$
if d is in centimeters the area in sq. inches	$=d^2 \times 0.121\ 736^*$
if d is in centimeters the area in sq. feet	$=d^2 \times 0.000\ 845\ 391^*$
if d is in inches the area in sq. centimeters	$=d^2 \times 5.067\ 09^*$
if d is in inches the area in sq. feet	$=d^2 \times 0.005\ 454\ 15^*$
if d is in feet the area in sq. centimeters	$=d^2 \times 729.662^*$
if d is in feet the area in sq. inches	$=d^2 \times 113.097^*$

SURFACES; Circular or Cross-section Measures. Usual.

Aprx. means within 2%; "sq." means square and is often used as a suffix instead of the exponent ⁽²⁾, being simpler for printing and type-writing; thus *sq. cm* for cm^2 ; *sq. ft* for ft^2 .

* Checked by L. A. Fischer, Asst. Phys. National Bureau of Standards.

		Logarithm
1 circular mil [CM]	$= 0.785\ 398^*$ sq. mil. Aprx. $\frac{8}{10}$	1.895 0899
"	$= 0.000\ 645\ 163^*$ Cmm. Aprx. $\frac{7}{11} + 1\ 000$..	4.809 6692
"	$= 0.000\ 506\ 709^*$ sq. mm. Aprx. $\frac{1}{2} + 1\ 000$.	4.704 7591
"	$= 0.000\ 001$ circular inch.....	6.000 0000
1 sq. mil [mil ²]	$= 1.273\ 24^*$ circular mils. Aprx. $\frac{1}{8}$	0.104 9101
"	$= 0.000\ 821\ 447^*$ circ. mm. Aprx. $\frac{1}{2} + 100$	4.914 5793
"	$= 0.000\ 645\ 163^*$ sq. millimeter. Aprx. $\frac{7}{11} + 1\ 000$	4.809 6692
"	$= 0.000\ 001$ sq. inch.....	6.000 0000
1 circular millimeter [Cmm]:		
$= 1\ 550.00^*$ circular mils. Aprx. $\frac{11}{7} \times 1\ 000$		3.190 3308
$= 1\ 217.36^*$ sq. mils. Aprx. $\frac{6}{5} \times 1\ 000$		3.085 4207
$= 0.785\ 398^*$ sq. millimeter. Aprx. $\frac{8}{10}$		1.895 0899
$= 0.01$ circular centimeter.....		2.000 0000
1 sq. millimeter [mm ²]	$= 1\ 973.52^*$ cir. mils. Aprx. $2\ 000$..	3.295 2409
"	$= 1\ 550.00^*$ sq. mils. Ap. $\frac{11}{7} \times 1\ 000$	3.190 3308
"	$= 1.273\ 24^*$ circ. mm. Aprx. $\frac{1}{8}$...	0.104 9101
"	$= 0.012\ 732\ 4^*$ circ. cm. Aprx. $\frac{1}{80}$	2.104 9101
"	$= 0.01$ sq. centimeter.....	2.000 0000
"	$= 0.001\ 550\ 00^*$ sq. in. Aprx. $\frac{2}{13} + 100$.	3.190 3308

1 circular centimeter [Cem]:

=	155 000.* circular mils. Aprx. $1\frac{1}{4} \times 100\ 000$	5.190 3308
=	121 736.* sq. mils. Aprx. $12 \times 10\ 000$	5.085 4207
=	100. circular millimeters.....	2.000 0000
=	78.539 8 * sq. millimeters. Aprx. 80.....	1.895 0899
=	0.785 398 * sq. centimeter. Aprx. $\frac{8}{10}$	1.895 0899
=	0.155 000 * circular inch. Aprx. $\frac{2}{13}$	1.190 3308
=	0.121 736 * sq. inch. Aprx. $12 \div 100$	1.085 4207
=	0.001 076 39 * circular foot. Aprx. $108 \div 100\ 000$	3.031 9683
=	0.000 845 391 * sq. foot. Aprx. $\frac{1}{12} \div 100$	4.927 0582

1 sq. centimeter [cm²]:

=	197 352.* circular mils. Aprx. $2 \times 100\ 000$	5.295 2409
=	155 000.* sq. mils. Aprx. $1\frac{1}{4} \times 100\ 000$	5.190 3308
=	127.324 * circular millimeters. Aprx. $\frac{1}{2} \times 1\ 000$	2.104 9101
=	100. sq. millimeters.....	2.000 0000
=	1.273 24 * circular centimeters. Aprx. 10%	0.104 9101
=	0.197 352 * circular inch. Aprx. $\frac{2}{10}$	1.295 2409
=	0.155 000 * sq. inch. Aprx. $\frac{2}{13}$	1.190 3308
=	0.01 * sq. decimeter.....	2.000 0000
=	0.001 370 50 * circular foot. Aprx. $1\frac{1}{8} \div 1\ 000$	3.136 8784
=	0.001 076 387 * sq. foot. Aprx. $108 \div 100\ 000$	3.031 9683

1 circular inch [Cin]:

=	1 000 000. circular mils.....	6.000 0000
=	785 338.* sq. mils. Aprx. $\frac{7}{8} \times 1\ 000\ 000$	5.895 0899
=	645.163 * circular millimeters. Aprx. $1\frac{1}{2} \times 100$	2.809 6692
=	506.709 * sq. millimeters. Aprx. $\frac{1}{2} \times 1\ 000$	2.704 7591
=	6.451 63 * circular centimeters. Aprx. $1\frac{1}{2}$	0.809 6692
=	5.067 09 * sq. centimeters. Aprx. 5.....	0.704 7591
=	0.785 398 * sq. inch. Aprx. $\frac{8}{10}$	1.895 0899
=	0.006 944 44 * circular foot. Aprx. $7 \div 1\ 000$	3.841 6375
=	0.005 454 15 * sq. foot. Aprx. $\frac{6}{11} \div 100$	3.736 7274

1 sq. inch [in²]:

=	1 273 240.* cir. mils. Aprx. $\frac{1}{8} \times 10\ 000\ 000$	6.104 9101
=	1 000 000. sq. mils.....	6.000 0000
=	821.447 * cir. mm. Aprx. $\frac{5}{6} \times 1\ 000$	2.914 5793
=	645.163 * sq. mm. Aprx. $1\frac{1}{2} \times 100$	2.809 6692
=	8.214 47 * cir. centimeters. Aprx. $\frac{5}{6} \times 10$	0.914 5793
=	6.451 63 * sq. cm. Aprx. $1\frac{1}{2}$ or $6\frac{1}{2}$	0.809 6692
=	1.273 24 * circular inches. Aprx. 10%	0.104 9101
=	0.064 516 3 * sq. decimeter. Aprx. $\frac{7}{11} \div 10$...	2.809 6692
=	0.008 841 94 * circular foot. Aprx. $9 \div 1\ 000$...	3.946 5476
=	0.006 944 44 * sq. foot. Aprx. $\frac{7}{1000}$	3.841 6375

1 sq. decimeter [dm²]:

=	100. sq. centimeters.....	2.000 0000
=	15.500 0* sq. inches. Aprx. $1\frac{1}{4} \times 10$	1.190 3308
=	0.107 638 7* sq. foot. Aprx. $11 \div 100$...	1.031 9683
=	0.01 sq. meter.....	2.000 0000
=	0.011 959 9* sq. yard. Aprx. $12 \div 1\ 000$	2.077 7253

1 circular foot [Cft]:

=	929.034* cir. cm. Aprx. $1\frac{1}{12} \times 1\ 000$...	2.968 0317
=	729.662* sq. cm. Aprx. $\frac{8}{11} \times 1\ 000$...	2.863 1216
=	144. circular ins. Aprx. $\frac{1}{4} \times 1\ 000$...	2.158 3625
=	113.097* sq. inches. Aprx. $\frac{1}{6} \times 1\ 000$...	2.053 4524
=	0.785 398* sq. foot. Aprx. $\frac{8}{10}$	1.895 0899

1 sq. foot [ft²] (Brit.):

=	0.999 994 2 sq. foot (U.S.). Aprx. 1. ...	1.999 9975
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1 sq. foot [ft²] (U.S.):

=	0.092 902 9 sq. meter. Aprx. $1\frac{1}{12} \div 10$...	2.968 0292
=	1 182.88* cir. cm. Aprx. $\frac{7}{6} \times 1\ 000$...	3.072 9418
=	929.034* sq. cm. Aprx. $1\frac{1}{12} \times 1\ 000$...	2.968 0317
=	183.346* cir. in. Aprx. $1\frac{1}{6} \times 100$	2.263 2723
=	144. sq. ins. Aprx. $\frac{1}{4} \times 1\ 000$...	2.158 3625
=	9.290 34* sq. dm. Aprx. $1\frac{1}{12} \times 10$...	0.968 0317
=	1.273 24* circular feet. Aprx. 10% ...	0.104 9101
=	1.000 005 7 sq. feet (Brit.). Aprx. 1. ...	0.000 0025
=	0.111 111* sq. yard, or $\frac{1}{9}$	1.045 7575
=	0.092 903 4* sq. meter. Aprx. $1\frac{1}{12} \div 10$...	2.968 0317

1 sq. yard [yd²] (Brit.):

=	0.999 994 3 sq. yard (U.S.). Aprx. 1. ...	1.999 9975
=	0.836 126 sq. meter. Aprx. $\frac{5}{6}$	1.922 2717

1 sq. yard [yd ²] (U. S.)=	8 361.31 * sq. cm. Ap. $\frac{5}{8} \times 10\ 000$	3.922 2742
"	= 1 296.* sq. ins. Aprx. 13×100	3.112 6050
"	= 83.613 1 * sq. dm. Aprx. $\frac{5}{8} \times 100$	1.922 2742
"	= 9. sq. feet.....	0.954 2425
"	= 1.000 005 7 sq. yds. (Brit.). Ap. 1.	0.000 0025
"	= 0.836 131 * sq. meter. Aprx. $\frac{5}{8}$..	1.922 2742
"	= 0.008 361 31 * are. Aprx. $\frac{5}{8} + 100$	3.922 2742
"	= 0.000 206 612 * acre. Ap. $21 \div 100\ 000$.	4.315 1546
1 sq. meter [m ²]=	10 000. sq. centimeters.....	4.000 0000
"	= 1 550.00 * sq. ins. Aprx. $1\frac{1}{4} \times 1\ 000$	3.190 3308
"	= 100. sq. decimeters.....	2.000 0000
"	= 10.763 93 sq. ft. (Brit.). Aprx. $1\frac{1}{11} \times 10$	1.031 9708
"	= 10.763 87 * sq. ft. (U. S.). Aprx. $1\frac{1}{11} \times 10$	1.031 9683
"	= 1.195 99 sq. yds. (Brit.). Aprx. add $\frac{1}{5}$	0.077 7283
"	= 1.195 99 * sq. yds. (U. S.). Aprx. add $\frac{1}{5}$	0.077 7258
"	= 0.01 are.	2.000 0000
"	= 0.000 247 104 * acre. Aprx. $\frac{1}{4} \div 1\ 000$	4.392 8804
1 are or ar [a]=	1 076.387 * sq. feet. Aprx. $1\frac{1}{11} \times 1\ 000$	3.031 9683
"	= 119.599 * sq. yards. Aprx. 120.....	2.077 7258
"	= 100. sq. meters.....	2.000 0000
"	= 10. meters square.....	1.000 0000
"	= 1. sq. decameter.....	0.000 0000
"	= 0.024 710 4 * acre. Aprx. $\frac{1}{4} \div 10$	2.392 8804
"	= 0.01 hectare.....	2.000 0000
1 acre [A]=	43 560.* sq. feet. Aprx. $\frac{1}{23} \times 1\ 000\ 000$	4.639 0879
"	= 4 840.* sq. yards. Aprx. 4 800.....	3.684 8454
"	= 4 046.87 * sq. meters. Aprx. $4 \times 1\ 000$	3.607 1196
"	= 208.710 * feet square. Aprx. 210.....	2.319 5440
"	= 40.468 7 * ares. Aprx. 40.....	1.607 1196
"	= 0.404 687 * hectare. Aprx. $\frac{4}{10}$	1.607 1196
"	= 0.004 046 87 * sq. kilometer. Aprx. $4 \div 1\ 000$	3.607 1196
"	= 0.001 562 50 * sq. mile. Aprx. $1\frac{1}{4} \div 1\ 000$	3.193 8200
1 hectare [ha]=	107 638.7 * sq. feet. Aprx. $1\frac{1}{11} \times 100\ 000$	5.031 9683
"	= 11 959.9 * sq. yards. Aprx. $12 \times 1\ 000$	4.077 7258
"	= 10 000. sq. meters.....	4.000 0000
"	= 100. ares.....	2.000 0000
"	= 2.471 04 * acres. Aprx. $1\frac{1}{4}$	0.392 8804
"	= 0.01 sq. kilometer.....	2.000 0000
"	= 0.003 861 01 * sq. mile. Aprx. $\frac{1}{26} \div 10$	3.586 7004
1 sq. kilometer [km ²]=	10 763 867.* sq. ft. Ap. $1\frac{1}{11} \times 10\ 000\ 000$	7.031 9683
"	= 1 195 985.* sq. yds. Aprx. $12 \times 100\ 000$	6.077 7258
"	= 1 000 000. sq. meters.....	6.000 0000
"	= 10 000. ares.....	4.000 0000
"	= 247.104 * acres. Aprx. $\frac{1}{4} \times 1\ 000$	2.392 8804
"	= 100. hectares.....	2.000 0000
"	= 0.386 101 * sq. mile. Aprx. $\frac{1}{26} \times 10$..	1.586 7004
1 sq. mile [ml ²]=	27 878 400.* sq. feet. Aprx. $1\frac{1}{4} \times 10\ 000\ 000$	7.445 2678
"	= 3 097 600.* sq. yards. Aprx. $31 \times 100\ 000$...	6.491 0253
"	= 2 589 999.* sq. meters. Aprx. $26 \times 100\ 000$..	6.413 2996
"	= 25 900.0 * ares. Aprx. $26 \times 1\ 000$	4.413 2996
"	= 640. acres.....	2.806 1800
"	= 259.000 * hectares. Aprx. 260.....	2.413 2996
"	= 2.590 00 * sq. kilometers. Aprx. $26 \div 10$	0.413 2996

SURFACES (continued). Unusual, Special Trade, or Obsolete.

1 milliare=	0.1 sq. meter.
1 centare, centar, or centaire=	10.763 87 sq. feet=1. sq. meter.
1 square (building)=	100. sq. feet.
1 deciare=	10. sq. meters=0.1 are.
1 sq. rod, or sq. pole, or sq. perch=	625. sq. links (surveyor's)=272 $\frac{1}{4}$
sq. feet=	30 $\frac{1}{4}$ sq. yards=25.293 sq. meters= $\frac{1}{160}$ acre.
1 sq. chain (Gunter's or surveyor's)=	4 356. sq. feet=484. sq. yards=
404.687 sq. meters=	16. sq. rods, poles, or perches=4.046 87 ares= $\frac{1}{10}$ acre=
0.040 468 7 hectare=	0.000 404 687 sq. kilometer=0.000 156 250 sq. mile.

1 sq. meter = 0.002 471 04 sq. chain. 1 are = 0.247 104 sq. chain. 1 acre = 10. sq. chains. 1 hectare = 24.710 4 sq. chains.
 1 **decare** (not used) = 1 000. sq. meters = 10. ares.
 1 **rood** [R] = 10 890. sq. feet = 1 210. sq. yards = 1 011.72 sq. meters = 40. sq. rods, poles, or perches = $\frac{1}{4}$ acre.
 1 **fardingdeal** (Brit.) = 1. rood.
 1 **circular acre** = 235.504 feet diameter.
 1 **section** (of land) = 1. mile square.
 1 **township** = 36. sq. miles.
 1 **sq. myriameter** or **miriameter** = 100. sq. kilometers = 38.610 1 sq. miles.

SURFACES (concluded). Foreign.

These are mostly obsolete as the metric system is now used in most foreign countries. The British measures are included among the U. S. measures, being very nearly, and sometimes quite, the same. The translated terms are merely synonymous, and not the exact equivalents.

Germany. Prussia 1 Morgen = 180 sq. Ruthen (rods). 1 Morgen = 25.532 25 ares = 2 553.225 sq. meters = 0.630 912 acres. According to Nystrom's Mechanics, 1 Berlin Morgen, great, = 6 786 sq. yards; ditto, small, = 3 054 sq. yards. 1 Hamburg Morgen = 11 545 sq. yards. 1 Hanover Morgen = 3 100 sq. yards. 1 Prussian Morgen = 3 053 sq. yards.

France. 1 arpent (acre) = 100 sq. perches (French, nearly same as U. S.) = 34.19 are, or 51.07 are = 0.844 849 acres, or 1.261 96 acres.

Austria. 1 Joch = 1 600 sq. Klafter = 5 755 sq. meters = 1.422 08 acres. 1 Vienna Joch = 6 889 sq. yards.

Sweden. 1 Tunmland = 56 000 sq. fot = 49.364 1 ares = 1.219 81 acres. According to Nystrom it is equal to 5 900 sq. yards.

Russia. 1 Dessatine = 2 400 sq. sashchn = 10 925 sq. meters = 2.699 61 acres. 13 066.2 sq. yards (Nystrom).

Switzerland. 1 Geneva arpent = 6 179 sq. yards; 1 faux = 7 855 sq. yards; 1 Zurich acre = 3 875.0 sq. yards.

Spain. 1 fanegada (since 1801) = 1.587 1 acres = 69 134.08 sq. feet; according to Nystrom it is equal to 5 500 sq. yards.

Japan. 1 cho (apparently not 1 cho length squared) = 10 tan of 10 se of 30 tsubo. 1 tsubo = 1 ken square = 3.31 square meters = 35.6 square feet. 1 square meter = 0.302 tsubo. 1 square foot = 0.028 1 tsubo. 1 cho = 2.45 acres.

Miscellaneous. (From Nystrom's Mechanics.) 1 fanegada, Canary Isles, = 2 422 sq. yards. 1 acre, Ireland, = 7 840 sq. yards. 1 acre, Scotland, = 6 150 sq. yards. 1 moggia, Naples, = 3 998 sq. yards. 1 Pezza, Rome, = 3 158 sq. yards. 1 Geira, Portugal, = 6 970 sq. yards.

Conversion Tables for Surfaces.

Sq. in. =	sq. cm.							
Sq. cm. =	.....	sq. ins.						
Sq. ft. =	.....	.....	sq. met.					
Sq. m. =	.....	.....	.....	sq. ft.	.....	sq. yds.		
Sq. yd. =	.....	.....	.....	.....	sq. met.	.....	hect' res.	
Acres =	.....	.....	.....	.....	.....	.....	.....	acres.
Hect' r. =	.....	.....	.....	.....	.....	.....	.....	.....
1	6.451 63	0.155 000	0.092 903	10.763 9	0.836 13	1.195 99	0.404 687	2.471 04
2	12.903 3	0.309 999	0.185 807	21.527 7	1.672 26	2.391 97	0.809 375	4.942 09
3	19.354 9	0.464 999	0.278 710	32.291 6	2.508 39	3.587 96	1.214 06	7.413 13
4	25.806 5	0.619 999	0.371 614	43.055 5	3.344 52	4.783 94	1.618 75	9.884 18
5	32.258 1	0.774 998	0.464 517	53.819 3	4.180 65	5.979 93	2.023 44	12.355 2
6	38.709 8	0.929 998	0.557 420	64.583 2	5.016 78	7.175 91	2.428 12	14.826 3
7	45.161 4	1.085 00	0.650 324	75.347 1	5.852 91	8.371 90	2.832 81	17.297 3
8	51.613 0	1.239 99	0.743 227	86.111 0	6.689 05	9.567 88	3.237 50	19.768 4
9	58.064 6	1.395 00	0.836 131	96.874 8	7.525 18	10.763 9	3.642 19	22.239 4
10	64.516 3	1.550 00	0.929 034	107.639	8.361 31	11.959 9	4.046 87	24.710 4

VOLUMES. Cubic and Capacity Measures.

The fundamental standard measures of volumes in the United States are; (a) the cubes of linear dimensions in terms of units based on the international meter; (b) the liter which is the volume of the mass of one international kilogram of pure water at its maximum density, and at 760 mm. barometric pressure; (c) the gallon, which is equal to exactly 231 cubic inches; (d) the bushel (the old Winchester bushel of England) which is equal to exactly 2 150.42 cubic inches. The inch here referred to is the one derived from this meter. The liter, being based on this kilogram, is the same in all the countries participating in the international convention. These four measures of volumes and capacities are those now used by the National Bureau of Standards in Washington and are in general use in this country. They are definite and accurate, except that the precise volume of the liter expressed in cubic centimeter is still slightly uncertain as explained below.

The liter is, according to the decision some years ago of the International Committee of Weights and Measures, defined as "the volume of the mass of one kilogram of pure water at its maximum density, and under normal atmospheric pressure." The accepted temperature, at present, at which the density of water is a maximum, is 4° C., but this may be altered slightly by subsequent determinations. The normal atmospheric pressure referred to is that exerted by a vertical column of mercury 760 mm. high, at latitude 45° and at sea level, the mercury having a density of 13.595 93. This definition of the liter has been adopted by the National Bureau of Standards. It was originally intended that the kilogram should be the weight of a cubic decimeter of water, thus making the liter exactly a cubic decimeter. The kilogram, however, being now fixed definitely as the weight of a certain piece of metal, and as this establishes the liter, it still remains to determine by measurement the precise volume of the liter in cubic decimeters. The International Bureau began this determination some five years ago, and the results thus far obtained indicate that the liter is about 25 parts in 1 000 000. greater than the cubic decimeter.† As this relation will always be subject to slight corrections, and as the difference is of no consequence in practice, the National Bureau of Standards has for the present assumed that the liter and the cubic decimeter are equivalent; this identity is assumed also in all the tables in this book. The difference above mentioned would at most affect only the fifth place of figures slightly, and generally only the sixth. The capacities of vessels are determined by weighing the water necessary to fill them, and not by measuring their dimensions (see the table of the weights and volumes of water).

The Customs Service and the Internal Revenue Bureau use the gallon of 231 cubic inches above referred to; it is the old British wine gallon. In these tables this gallon and the measures based on it are indicated as "liquid; U. S." to distinguish them from the "dry; U. S." measures and the Imperial or "Brit." measures.

The gallon and liter are the units for measuring liquids, while the bushel and liter are the units for dry measures, as for grain, fruits, vegetables, etc. The "dry" measures are about one sixth greater than the corresponding "liquid" measures; accurately:

dry measures $\times 1.163\ 65$ (aprx. add $\frac{1}{6}$) = liquid meas. (log 0.065 8213)

liquid measures $\times 0.859\ 367$ (aprx. subtr. $\frac{1}{6}$) = dry meas. (log 1.934 1787)

The fluid ounce is in use chiefly by apothecaries. The barrel is no fixed unit, and no value of a barrel has ever been adopted by Congress; in the Customs Service and Internal Revenue Bureau every barrel is gauged.

Concerning the bushel the Revised Statutes of the United States, under the ascertainment of duties on grain, chapter 6, sec. 2919, says: "For the purpose of estimating the duties on importations of grain, the num-

† Guillaume in a recent book on the International Bureau of Weights and Measures states that this Bureau has found the mass of a cubic decimeter of water at 4° C. to be 0.999 955 kg. This makes a liter about 45 parts in 1 000 000. greater than a cubic decimeter. But it seems that no formal adoption of any value has yet been made.

ber of bushels shall be ascertained by weight, instead of by measuring; and sixty pounds of wheat, fifty-six pounds of corn, fifty-six pounds of rye, forty-eight pounds of barley, thirty-two pounds of oats, sixty pounds of pease and forty-two pounds of buckwheat, avoirdupois weight, shall respectively be estimated as a bushel."

In Great Britain the liter is exactly the same as in the United States. The gallon, which in this country is often called the Imperial or British gallon, was originally defined as the volume of "ten imperial pounds of distilled water, weighed in air against brass weights, with the water and the air at the temperature of 62° Fahrenheit, the barometer being at 30 inches." According to the latest computations of the Standards Office in London, the British or Imperial gallon is equal to 4.545 963 1 liters; this value was made legal in 1896† in Great Britain, and is the one used as a basis throughout these tables, even for computing such values as the gallon in cubic inches; the figures are therefore quite consistent throughout, except that the U. S. yard, foot, inch are used, which are about 3 parts in one million larger than the British, a difference too small to be considered in any but the most refined physical measurements. Owing to this difference, the U. S. cubic yard, cubic foot, etc., are about 9 parts in one million greater than the British. Hence to reduce these values in these tables to British yards, feet, and inches, when very great accuracy is required, subtract 9 parts for every million from all the values of a cubic yard, cubic foot, and cubic inch given in terms of *other* units than yards, feet, and inches; for instance, add this correction in the value of a cb. foot in cb. meters, but not in cb. inches, as the latter is the same for both; or add 9 parts for every million to all the values of *other* units given in terms of cubic yards, cubic feet, and cubic inches. This will never affect the fifth place of figures by more than one unit, and generally not that much.

In Great Britain the measures of capacities (gallons, quarts, etc.) are the same for liquid as for dry materials. The British measures of capacity differ but little from the corresponding *dry* measures in the United States; accurately:

Brit. meas. $\times 1.032\ 02$ (aprx. add $\frac{1}{30}$) = dry U. S. meas. (log 0.013 6888)

dry U. S. meas. $\times 0.968\ 972$ (aprx. sub. $\frac{1}{30}$) = Brit. meas. (log 1.986 3112)

The British measures of capacity are about 20% greater than the corresponding *liquid* measures in the United States; accurately:

Brit. meas. $\times 1.200\ 91$ (aprx. add $\frac{1}{5}$) = liquid U. S. meas. (log 0.079 5101)

liquid U. S. meas. $\times 0.832\ 602\ 4$ (aprx. $\frac{1}{12}$) = Brit. meas. (log 1.920 4899)

The U. S. and the British apothecary fluid measures, smaller than the pint, differ very little from each other, almost exactly 4%, the former being the greater; for conversion add 4% to the quantity expressed in the U. S. measures, or subtract 4% when expressed in British measures.

VOLUMES. Cubic and Capacity Measures. Usual.

** Accepted by the National Bureau of Standards.

* Checked by L. A. Fischer. Asst. Phys. National Bureau of Standards.

Apxr. means within 2%.

ap. means apothecary measures; *cb.* means cubic, and is often used as a suffix instead of the exponent (³), being simpler for printing and type writing; thus cb. cm. for cm.³, or cb. ft. for ft.³

1 cb. centimeter [cm ³] or 1 milliliter [ml]:	Logarithm
= 1 000. cb. millimeters.	3.000 0000
= 0.061 023 4* cb. inch. Aprx. 6 ÷ 100.	2.785 4962
= 0.01 deciliter.	2.000 0000
= 0.002 113 36 pint* (liquid; U. S.). Aprx. 21 ÷ 10 000.	3.324 9742
= 0.001 816 16* pint (dry; U. S.). Aprx. $\frac{2}{11}$ ÷ 100.	3.259 1529
= 0.001 759 80 pint (Brit.). Aprx. $\frac{7}{4}$ ÷ 1 000.	3.245 4641
= 0.001 056 68* quart (liquid; U. S.). Aprx. $2\frac{1}{2}$ ÷ 10 000.	3.023 9442
= 0.001 liter or cb. decimeter.	3.000 0000
= 0.000 908 078* quart (dry; U. S.). Aprx. 9 ÷ 10 000.	4.958 1229
= 0.000 879 902 quart (Brit.). Aprx. $\frac{7}{8}$ ÷ 1 000.	4.944 4341

† Formerly the legal value is said to have been 4.543 46 liters.

1 cb. inch [in ³]	=	16 387.16* cb. mm. Aprx. $\frac{1}{16} \times 100\ 000$...	4.214 5038
"	=	16.387 16* cb. cm. or ml. Aprx. $\frac{1}{16} \times 100$...	1.214 5038
"	=	0.163 871 6* deciliters. Aprx. $\frac{1}{16}$...	1.214 5038
"	=	0.034 632 0* pt. (liq.; U. S.). Aprx. $\frac{1}{16} \div 100$...	2.539 4780
"	=	0.029 761 6* pt. (dry; U. S.). Aprx. $\frac{3}{16} \div 100$...	2.473 6567
"	=	0.028 838 2 pt. (Brit.). Aprx. $\frac{3}{16} \div 10$...	2.459 9679
"	=	0.017 316 0* qt. (liq.; U. S.). Aprx. $\frac{1}{16} \div 100$...	2.238 4480
"	=	0.016 387 16 liter or cb. dm. Aprx. $\frac{1}{16} \div 10$...	2.214 5038
"	=	0.014 880 8* qt. (dry; U. S.). Aprx. $\frac{3}{16} \div 100$...	2.172 6267
"	=	0.014 419 1 qt. (Brit.). Aprx. $\frac{1}{16} \div 10$...	2.158 9379
"	=	0.004 329 00* gal. (liq.; U. S.). Aprx. $\frac{3}{16} \div 100$...	2.636 3880
"	=	0.003 604 77 gal. (Brit.). Aprx. $\frac{1}{16} \div 100$...	3.556 8779
"	=	0.000 578 704* cb. foot. Aprx. $\frac{1}{16} \div 1\ 000$...	4.762 4563
1 deciliter [dl]	=	100. cb. centimeters.	2.000 0000
"	=	6.102 34* cb. inches. Aprx. $\frac{6}{10}$...	0.785 4962
"	=	0.211 336* pt. (liq.; U. S.). Aprx. $\frac{21}{100}$...	1.324 9742
"	=	0.181 616* pt. (dry; U. S.). Aprx. $\frac{21}{100}$...	1.259 1529
"	=	0.175 980 pint (Brit.). Aprx. $\frac{1}{10} \div 10$...	1.245 4647
"	=	0.105 668* qt. (liq.; U. S.). Aprx. $\frac{2}{10} \div 100$...	1.023 9442
"	=	0.1 liter or cb. decimeter.	1.000 0000
"	=	0.090 807 8* quart (dry; U. S.). Aprx. $\frac{1}{10}$...	2.958 1229
"	=	0.087 990 2 quart (Brit.). Aprx. $\frac{7}{8} \div 10$...	2.944 4341
"	=	0.026 417 0* gal. (liq. U. S.). Aprx. $\frac{8}{10} \div 100$...	2.421 8842
"	=	0.021 997 5 gal. (Brit.). Aprx. $\frac{22}{10} \div 1\ 000$...	2.342 3741
"	=	0.003 531 45* cb. foot. Aprx. $\frac{1}{10} \div 1\ 000$...	3.547 9525
1 pint [pt] (liquid; U. S.):	=	473.179* cb. centimeters. Aprx. $\frac{1}{21} \times 10\ 000$...	2.675 0258
"	=	28.875* cb. inches. Aprx. $\frac{2}{7} \times 100$...	1.460 5220
"	=	16. fluid ounces (ap. U. S.).	1.204 1200
"	=	4.731 79* deciliters. Aprx. $4\frac{3}{4}$...	0.675 0258
"	=	4. gills (liquid; U. S.).	0.602 0600
"	=	0.859 367* pint (dry; U. S.). Aprx. $\frac{9}{10}$...	1.934 1787
"	=	0.832 702 4 pint (Brit.). Aprx. $\frac{5}{6}$...	1.920 4899
"	=	0.5 quart (liquid; U. S.); or $\frac{1}{2}$...	1.698 9700
"	=	0.473 179* liter or cb. decimeter. Aprx. $\frac{1}{21} \times 10$...	1.675 0258
"	=	0.125 gallon (liquid; U. S.); or $\frac{1}{8}$...	1.096 9100
"	=	0.016 710 1* cb. foot. Aprx. $\frac{1}{16} \div 10$...	2.222 9783
"	=	0.004 731 79* hectoliter. Aprx. $\frac{1}{21} \div 10$...	3.675 0258
"	=	0.000 618 891* cb. yard. Aprx. $\frac{5}{8} \div 1\ 000$...	4.791 6145
"	=	0.000 473 179* cb. meter or stere. Aprx. $\frac{1}{21} \div 100$...	4.675 0258
1 pint [pt] (dry; U. S.):	=	550.614* cb. centimeters. Aprx. 550.	2.740 8471
"	=	33.600 312* cb. inches. Aprx. $\frac{1}{10} \times 100$...	1.526 3433
"	=	5.506 14* deciliters. Aprx. $5\frac{1}{2}$ or $1\frac{1}{2}$...	0.740 8471
"	=	1.163 65* pints (liquid; U. S.). Aprx. $1\frac{1}{10}$ or $\frac{7}{10}$...	0.065 8213
"	=	0.968 972 pint (Brit.). Aprx. subtract $\frac{1}{30}$...	1.986 3112
"	=	0.550 614* liter or cb. decimeter. Aprx. $\frac{1}{12} \div 10$...	1.740 8471
"	=	0.5 quart (dry; U. S.); or $\frac{1}{2}$...	1.698 9700
"	=	0.121 122 gallon (Brit.). Aprx. $\frac{5}{8} \div 10$...	1.083 2215
"	=	0.062 500* peck (U. S.); or $\frac{5}{8} \div 10$...	2.795 8800
"	=	0.019 444 6* cb. foot. Aprx. $\frac{21}{11} \div 100$...	2.288 7996
"	=	0.015 625* bushel (U. S.). Aprx. $1\frac{1}{4} \div 100$...	2.193 8200
"	=	0.005 506 14* hectoliter. Aprx. $\frac{1}{12} \div 1\ 000$...	3.740 8471
"	=	0.000 720 171* cb. yard. Aprx. $\frac{5}{4} \div 1\ 000$...	4.857 4358
"	=	0.000 550 614* cb. meter or stere. Aprx. $\frac{1}{12} \div 10\ 000$...	4.740 8471
1 pint [pt] (Brit.):	=	568.245 39 cb. centimeters. Aprx. $\frac{4}{7} \times 1\ 000$...	2.754 5359
"	=	34.676 2 cb. inches. Aprx. $\frac{1}{2} \times 10$...	1.540 0321
"	=	20. fluid ounces (ap. Brit.).	1.301 0300
"	=	5.682 453 9 deciliters. Aprx. $5\frac{3}{8}$...	0.754 5359
"	=	4. gills (Brit.).	0.602 0600
"	=	1.200 91 pints (liquid; U. S.). Aprx. $1\frac{1}{10}$...	0.079 5101
"	=	1.032 02 pints (dry; U. S.). Aprx. $1\frac{1}{80}$...	0.013 6888
"	=	0.568 245 39 liter or cb. decimeter. Aprx. $\frac{4}{7}$...	1.754 5359
"	=	0.5 quart (Brit.); or $\frac{1}{2}$...	1.698 9700
"	=	0.125 gallon (Brit.); or $\frac{1}{8}$...	1.096 9100
"	=	0.062 5 peck (Brit.); or $\frac{5}{8} \div 10$...	2.795 8800

1 pint [pt] (Brit.).

=	0.020 067 3 cb. foot.	Aprx. $2 \div 100$	2.302 4884
=	0.015 625 bushel (Brit.).	Aprx. $1\frac{1}{4} \div 100$	2.193 8200
=	0.005 682 453 9 hectoliter.	Aprx. $\frac{4}{7} \div 100$	3.754 5359
=	0.000 743 232 cb. yard.	Aprx. $\frac{3}{4} \div 1\ 000$	4.871 1246
=	0.000 568 245 39 cb. meter or stere.	Aprx. $\frac{4}{7} \div 1\ 000$	4.754 5359

1 quart [qt] (liquid; U. S.).

=	946.359* cb. centimeters.	Aprx. $\frac{2}{21} \times 10\ 000$	2.976 0558
=	57.750 0* cb. inches.	Aprx. $\frac{4}{7} \times 100$	1.761 5520
=	9.463 59* deciliters.	Aprx. $\frac{2}{21} \times 100$	0.976 0558
=	8. gills (liquid; U. S.).	.....	0.903 0900
=	2. pints (liquid; U. S.).	.....	0.301 0300
=	0.946 359* liter or cb. decimeter.	Aprx. subtr. $\frac{1}{20}$	1.976 0558
=	0.859 367* quart (dry; U. S.).	Aprx. $\frac{9}{7}$	1.934 1787
=	0.832 702 4 quart (Brit.).	Aprx. $\frac{5}{6}$	1.920 4899
=	0.25* gallon (liquid; U. S.); or $\frac{1}{4}$.	.....	1.397 9400
=	0.208 170 gallon (Brit.).	Aprx. $21 \div 100$	1.318 4299
=	0.033 420 1* cb. foot.	Aprx. $\frac{1}{3} \div 10$	2.524 0083
=	0.009 463 59* hectoliter.	Aprx. $\frac{2}{21} \div 10$	3.976 0558
=	0.001 237 78* cb. yard.	Aprx. $\frac{1}{8} \div 100$	3.092 6445
=	0.000 946 359* cb. meter or stere.	Aprx. $\frac{2}{21} \div 100$	4.976 0558

1 cb. decimeter [dm³] = 1. liter which see for values

0.000 0000

1 liter [l] =

=	1 000. cb. centimeters.	.....	3.000 0000
"	=	61.023 4* cb. inches.	Aprx. 60.....
"	=	10. deciliters.	.....
"	=	2.113 36* pints (liquid; U. S.).	Aprx. $2\frac{1}{10}$
"	=	1.816 16* pints (dry; U. S.).	Aprx. $2\frac{9}{11}$
"	=	1.759 80 pints (Brit.).	Aprx. $1\frac{3}{4}$ or $\frac{7}{4}$
"	=	1.056 68* quarts (liquid; U. S.).	Aprx. add $\frac{1}{20}$..
"	=	1. cb. decimeter	.....
"	=	0.908 078* quart (dry; U. S.).	Aprx. $\frac{9}{10}$
"	=	0.879 902 quart (Brit.).	Aprx. $\frac{7}{8}$
"	=	0.264 170* gallon (liquid; U. S.).	Aprx. $\frac{8}{30}$
"	=	0.219 975 gallon (Brit.).	Aprx. $22 \div 100$
"	=	0.113 510 peck (U. S.).	Aprx. $\frac{8}{7} \div 10$
"	=	0.109 988 peck (Brit.).	Aprx. $11 \div 100$
"	=	0.035 314 5 cb. foot.	Aprx. $\frac{7}{2} \div 100$
"	=	0.028 377 4 bushel (U. S.).	Aprx. $\frac{2}{7} \div 10$
"	=	0.027 496 9 bushel (Brit.).	Aprx. $1\frac{1}{4} \div 100$
"	=	0.01 hectoliter.	.....
"	=	0.001 307 94 cb. yard.	Aprx. $13 \div 10\ 000$
"	=	0.001 cb. meter or stere.	.....

1 quart [qt] (dry; U. S.):

=	1 101.23 cb. centimeters.	Aprx. 1 100.....	3.041 8771
=	67.200 625 cb. inches.	Aprx. $\frac{2}{3} \times 100$	1.827 3733
=	11.012 3 deciliters.	Aprx. 11.....	1.041 8771
=	2. pints (dry; U. S.).	.....	0.301 0300
=	1.163 65 quarts (liquid; U. S.).	Aprx. add $\frac{1}{6}$	0.065 8213
=	1.101 23 liters or cb. decimeters.	Aprx. $1\frac{1}{10}$	0.041 8771
=	0.968 972 quart (Brit.).	Aprx. subtract $\frac{1}{30}$	1.986 3112
=	0.242 243 gallon (Brit.).	Aprx. $24 \div 100$	1.384 2512
=	0.125* peck (U. S.); or $\frac{1}{8}$.	.....	1.096 9100
=	0.038 889 3* cb. foot.	Aprx. $\frac{1}{26}$	2.589 8296
=	0.031 250* bushel (U. S.).	Aprx. $31 \div 1\ 000$	2.494 8500
=	0.011 012 3 hectoliter.	Aprx. $11 \div 1\ 000$	2.041 8771
=	0.001 440 34* cb. yard.	Aprx. $\frac{1}{7} \div 100$	3.158 4658
=	0.001 101 23 cb. meter or stere.	Aprx. $11 \div 10\ 000$	3.041 8771

1 quart [qt] (Brit.):

=	1 136.490 8 cb. centimeters.	Aprx. $\frac{8}{7} \times 1\ 000$	3.055 5859
=	69.352 5 cb. inches.	Aprx. 70.....	1.841 0621
=	11.364 908 deciliters.	Aprx. $\frac{8}{7} \times 10$	1.055 5859
=	8. gills (Brit.).	.....	0.903 0900
=	2. pints (Brit.).	.....	0.301 0300
=	1.200 91 quarts (liquid; U. S.).	Aprx. $1\frac{1}{6}$	0.079 5101
=	1.136 490 8 liters or cb. decimeters.	Aprx. add $\frac{1}{7}$	0.055 5859
=	1.032 02 quarts (dry; U. S.).	Aprx. $1\frac{1}{30}$	0.013 3608
=	0.300 227 gallon (liquid; U. S.).	Aprx. $\frac{8}{10}$	1.477 4501

1 quart [qt] (Brit.).

=	0.25 gallon (Brit.); or $\frac{1}{4}$	1.397 9400
=	0.125 peck (Brit.); or $\frac{1}{8}$	1.096 9100
=	0.040 134 6 cb. foot. Aprx. $4 \div 100$	2.603 5184
=	0.031 250 bushel (Brit.). Aprx. $31 \div 1\ 000$	2.494 8500
=	0.011 364 908 hectoliter. Aprx. $\frac{8}{7} + 100$	2.055 5659
=	0.001 486 46 cb. yard. Aprx. $\frac{3}{2} + 1\ 000$	3.172 1546
=	0.001 136 490 8 cb. meter or stere. Aprx. $\frac{8}{7} + 1\ 000$	3.055 5659

1 gallon [gal] (liquid; U. S.):

=	3 785.43* cb. centimeters. Aprx. $\frac{3}{8} \times 10\ 000$	3.578 1158
=	231.** cb. inches. Aprx. $\frac{7}{8} \times 100$	2.363 6120
=	37.854 3* deciliters. Aprx. $\frac{3}{8} \times 100$	1.578 1158
=	32. gills (liquid; U. S.).....	1.505 1500
=	8. pints (liquid; U. S.).....	0.903 0900
=	4. quarts (liquid; U. S.).....	0.602 0600
=	3.785 43* liters or cb. decimeters. Aprx. $\frac{3}{8} \times 10$	0.578 1158
=	0.832 702 4 gallon (Brit.). Aprx. $\frac{5}{6}$	1.920 4899
=	0.133 681* cb. foot. Aprx. $\frac{4}{3} + 10$	1.126 0683
=	0.037 854 3* hectoliter. Aprx. $\frac{3}{8} \times 10$	2.578 1158
=	0.004 951 13* cb. yard. Aprx. $\frac{1}{2} + 100$	3.694 7045
=	0.003 785 43* cb. meter or stere. Aprx. $\frac{3}{8} + 100$	3.578 1158

1 Imperial gallon [see gallon (Brit.)].

1 gallon [gal] (Brit.).

=	4 545.963 1 cb. centimeters. Aprx. $\frac{9}{2} \times 1\ 000$	3.657 6259
=	277.410 cb. inches. Aprx. $\frac{1}{4} \times 100$	2.443 1221
=	32. gills (Brit.).....	1.505 1500
=	8. pints (Brit.).....	0.903 0900
=	4.545 963 1 liters or cb. decimeters. Aprx. $4\frac{1}{2}$	0.657 6259
=	4. quarts (Brit.).....	0.602 0600
=	1.200 91 gallons (liquid; U. S.). Aprx. $1\frac{1}{6}$	0.079 5101
=	0.160 538 cb. foot. Aprx. $\frac{8}{5} \div 10$	1.205 5784
=	0.125 bushel (Brit.); or $\frac{1}{8}$	1.096 9100
=	0.045 459 631 hectoliter. Aprx. $\frac{9}{2} \div 100$	2.657 6259
=	0.005 945 86 cb. yard. Aprx. $6 \div 1\ 000$	3.774 2146
=	0.004 545 963 1 cb. meter or stere. Aprx. $\frac{9}{2} \div 1\ 000$	3.657 6259

1 peck [pk] (U. S.)=

=	8 809.82* cb. cms. Aprx. $\frac{7}{8} \times 10\ 000$..	3.944 9671
=	537.605 0* cb. ins. Aprx. $\frac{9}{11} \times 1\ 000$..	2.730 4633
=	16. pints (dry; U. S.).....	1.204 1200
=	8.809 82* lit's or cb. dms. Aprx. $\frac{7}{8} \times 10$	0.944 9671
=	8. quarts (dry; U. S.).....	0.903 0900
=	1.937 94 gals. (Brit.). Aprx. $2\frac{1}{11}$	0.287 3412
=	0.968 972 pk. (Brit.). Aprx. sub. $\frac{1}{40}$..	1.986 3112
=	0.311 114* cb. foot. Aprx. $31 \div 100$..	1.492 9190
=	0.25 bushel (U. S.) or $\frac{1}{4}$	1.397 9400
=	0.088 098 2* hectoliter. Aprx. $\frac{7}{8} + 10$	2.944 9671
=	0.011 522 7* cb. yard. Aprx. $\frac{8}{7} \div 100$	2.061 5558
=	0.008 809 82* cb. meter. Aprx. $\frac{7}{8} \div 100$	3.944 9671

1 peck [pk] (Brit.)=

=	9 091.926 2 cb. cms. Aprx. 9 000.....	3.958 6559
=	554.820 cb. ins. Aprx. $1\frac{1}{2} \times 100$	2.744 1521
=	16. pints (Brit.).....	1.204 1200
=	9.091 926 2 liters or cb. dms. Aprx. 9..	0.958 6559
=	8. quarts (Brit.).....	0.903 0900
=	2. gallons (Brit.).....	0.301 0300
=	1.032 02 pecks (U. S.). Aprx. $1\frac{1}{40}$..	0.013 6888
=	0.321 076 cb. foot. Aprx. $32 \div 100$..	1.506 6084
=	0.25 bushel (Brit.) or $\frac{1}{4}$	1.397 9400
=	0.090 919 262 hectoliter. Aprx. $9 \div 100$..	2.958 6559
=	0.011 891 7 cb. yard. Aprx. $12 \div 1\ 000$	2.075 2446
=	0.009 091 926 2 cb. meter. Aprx. $9 \div 1\ 000$.	3.958 6559

1 cb. foot [ft³]=

=	28 317.0* cb. cms. Aprx. $\frac{3}{4} \times 100\ 000$	4.452 0475
=	1 728.* cb. inches. Aprx. $\frac{1}{4} \times 1\ 000$	3.237 5437
=	59.844 2 pints (liq.; U. S.). Aprx. 60.....	1.777 0217
=	51.428 09 pints (dry; U. S.). Aprx. 51.....	1.711 2004
=	49.832 4 pints (Brit.). Aprx. 50.....	1.697 5116
=	29.922 1 quarts (liq.; U. S.). Aprx. 30....	1.475 9917
=	28.317 0* liters or cb. dms. Aprx. $\frac{3}{4} \times 100$...	1.452 0475
=	25.714 05* quarts (dry; U. S.). Aprx. 26....	1.410 1704

1 cb. foot [ft ³]	=	24.916 2	quarts (Brit.).	Aprx. 25.	1.396 4816
"	=	7.480 52*	gals. (liq.; U. S.).	Aprx. $\frac{3}{4} \times 10$.	0.873 9317
"	=	6.428 51*	gallons (dry; U. S.).	Aprx. $6\frac{1}{2}$.	0.808 1104
"	=	6.229 05	gallons (Brit.).	Aprx. $6\frac{1}{4}$.	0.794 4216
"	=	3.214 26*	pecks (U. S.).	Aprx. $3\frac{1}{4}$.	0.507 0804
"	=	3.114 52	pecks (Brit.).	Aprx. $3\frac{1}{6}$.	0.493 3916
"	=	0.803 564*	bushel (U. S.).	Aprx. $\frac{4}{5}$.	1.905 0704
"	=	0.778 630	bushel (Brit.).	Aprx. $\frac{7}{9}$.	1.891 3316
"	=	0.283 170*	hectoliter.	Aprx. $\frac{2}{7}$.	1.452 0475
"	=	0.037 037 0*	cb. yard.	Aprx. $\frac{3}{8} \div 10$.	2.568 6362
"	=	0.028 317 0*	cb. meter or stere.	Aprx. $\frac{2}{7} \div 10$.	2.452 0475
1 bushel [bu] (U. S.):					
=		35 239.28*	cb. centimeters.	Aprx. $\frac{7}{2} \times 10\ 000$.	4.547 0271
=		2 150.420 0**	cb. inches.	Aprx. $15\frac{1}{4} \times 1\ 000$.	3.332 5233
=		64.	pints (dry; U. S.).		1.806 1800
=		35.239 28*	liters or cb. decimeters.	Aprx. 35.	1.547 0271
=		32.	quarts (dry; U. S.).		1.505 1500
=		7.751 78	gallons (Brit.).	Aprx. $7\frac{3}{4}$.	0.889 4012
=		4.	pecks (U. S.).		0.602 0800
=		1.244 46*	cb. feet.	Aprx. $1\frac{1}{4}$.	0.094 9796
=		0.968 972	bushel (Brit.).	Aprx. subtr. $\frac{1}{30}$.	1.986 3112
=		0.352 392 8*	hectoliter.	Aprx. $\frac{7}{2} \div 10$.	1.547 0271
=		0.125	quarter (U. S.) or $\frac{1}{8}$.		1.096 9100
=		0.046 091 0*	cb. yard.	Aprx. $\frac{5}{11} \div 10$.	2.663 6158
=		0.035 239 28*	cb. meter or stere.	Aprx. $\frac{7}{2} \div 100$.	2.547 0271
1 bushel [bu] (Brit.):					
=		36 367.704 8	cb. centimeters.	Aprx. $\frac{4}{11} \times 100\ 000$.	4.560 7159
=		2 219.28	cb. inches.	Aprx. $\frac{2}{9} \times 10\ 000$.	3.346 2121
=		64.	pints (Brit.).		1.806 1800
=		36.367 704 8	liters or cb. decimeters.	Aprx. $\frac{4}{11} \times 100$.	1.560 7159
=		32.	quarts (Brit.).		1.505 1500
=		8.	gallons (Brit.).		0.903 0900
=		4.	pecks (Brit.).		0.602 0600
=		1.284 31	cb. feet.	Aprx. $\frac{9}{7}$.	0.108 6684
=		1.032 02	bushels (U. S.).	Aprx. add $\frac{1}{30}$.	0.013 6888
=		0.125	quarter (Brit.) or $\frac{1}{8}$.		1.096 9100
=		0.047 566 9	cb. yard.	Aprx. $48 \div 1\ 000$.	2.677 3046
=		0.036 367 704 8	cb. meter or stere.	Aprx. $\frac{4}{11} \div 10$.	2.560 7159
1 hectoliter [hl]	=	6 102.34*	cb. inches.	Aprx. 6 000.	3.785 4962
"	=	211.336	pints (liq.; U. S.).	Aprx. 210.	2.324 9742
"	=	181.616*	pts. (dry; U. S.).	Aprx. $\frac{1}{6} \times 100$.	2.259 1529
"	=	175.980	pints (Brit.).	Aprx. $\frac{7}{4} \times 100$.	2.245 4641
"	=	105.668	quarts (liquid; U. S.).	Aprx. 106.	2.023 9442
"	=	100.	liters or cb. decimeter.		2.000 0000
"	=	90.807 8	quarts (dry; U. S.).	Aprx. 90.	1.958 1229
"	=	87.990 2	quarts (Brit.).	Aprx. $\frac{7}{8} \times 100$.	1.944 4341
"	=	26.417 0	gals. (liq.; U. S.).	Aprx. $\frac{8}{3} \times 10$.	1.421 8842
"	=	21.997 5	gallons (Brit.).	Aprx. 22.	1.342 3741
"	=	11.351 0	pecks (U. S.).	Aprx. $\frac{8}{7} \times 10$.	1.055 0329
"	=	10.998 8	pecks (Brit.).	Aprx. 11.	1.041 3441
"	=	3.531 45	cb. feet.	Aprx. $3\frac{1}{2}$ or $\frac{7}{2}$.	0.547 9525
"	=	2.837 74	bushels (U. S.).	Aprx. $\frac{2}{7} \times 10$.	0.452 9729
"	=	2.749 69	bushels (Brit.).	Aprx. $\frac{1}{4}$.	0.439 2841
"	=	0.130 794	cb. yard.	Aprx. $13 \div 100$.	1.116 5887
"	=	0.1	cb. meter or stere.		1.000 0000
1 cb. yard [yd ³]	=	46 656.	cb. inches.	Aprx. $1\frac{1}{3} \times 10\ 000$.	4.668 9075
"	=	1 615.79	pints (liq.; U. S.).	Aprx. $\frac{8}{5} \times 1\ 000$.	3.208 3855
"	=	1 388.56	pints (dry; U. S.).	Aprx. $\frac{7}{5} \times 1\ 000$.	3.142 5642
"	=	1 345.47	pints (Brit.).	Aprx. $\frac{4}{3} \times 1\ 000$.	3.128 8754
"	=	807.896	quarts (liquid; U. S.).	Aprx. 800.	2.907 3555
"	=	764.559	liters or cb. dms.	Aprx. $\frac{3}{4} \times 1\ 000$.	2.883 4113
"	=	694.279	quarts (dry; U. S.).	Aprx. 700.	2.841 5342
"	=	672.737	quarts (Brit.).	Aprx. $\frac{2}{3} \times 1\ 000$.	2.827 8454
"	=	201.974	gallons (liq.; U. S.).	Aprx. 200.	2.305 2955
"	=	168.184	gallons (Brit.).	Aprx. $\frac{1}{6} \times 1\ 000$.	2.225 7854
"	=	86.784 9	pecks (U. S.).	Aprx. $\frac{7}{8} \times 100$.	1.938 4442
"	=	84.092 1	pecks (Brit.).	Aprx. $\frac{5}{6} \times 100$.	1.924 7554

1 cb. yard [yd ³]=	27. cb. feet. Aprx. $\frac{8}{3} \times 10$	1.431 3838
"	= 21.696 2 bushels (U. S.). Aprx. $\frac{11}{6} \times 10$...	1.336 3842
"	= 21.023 0 bushels (Brit.). Aprx. 21.....	1.322 6954
"	= 0.764 559 cb. meter or stere. Aprx. $\frac{3}{4}$	1.883 4113
1 cb. meter [m ³] or stere [s]:		
= 61 023.4	cb. inches. Aprx. 60 000.	4.785 4962
= 2 113.36	pints (liquid; U. S.). Aprx. 2 100	3.324 9742
= 1 816.15	pints (dry; U. S.). Aprx. $\frac{11}{6} \times 1 000$	3.259 1529
= 1 759.80	pints (Brit.). Aprx. $\frac{7}{4} \times 1 000$	3.245 4641
= 1 056.68	quarts (liquid; U. S.). Aprx. $\frac{21}{2} \times 100$	3.023 9442
= 1 000.	liters or cb. decimeters.....	3.000 0000
= 908.078	quarts (dry; U. S.). Aprx. 900.	2.958 1229
= 879.902	quarts (Brit.). Aprx. $\frac{7}{8} \times 1 000$	2.944 4341
= 264.170	gallons (liquid; U. S.). Aprx. $\frac{8}{3} \times 100$	2.421 8842
= 219.975	gallons (Brit.). Aprx. 220.....	2.342 3741
= 113.510	pecks (U. S.). Aprx. $\frac{8}{7} \times 100$	2.055 0329
= 109.988	pecks (Brit.). Aprx. 110.	2.041 3441
= 35.314 5	cb. feet. Aprx. $\frac{7}{2} \times 10$	1.547 9525
= 28.377 4	bushels (U. S.). Aprx. $\frac{7}{4} \times 100$	1.452 9729
= 27.496 9	bushels (Brit.). Aprx. $\frac{11}{4} \times 10$	1.439 2841
=	10. hectoliters.	1.000 0000
= 1.307 94	cb. yards. Aprx. $1\frac{1}{3}$	0.116 5887

Conversion Tables for Volumes. Cubical; Capacity.

Cb.ins.=	cb.cms								fluid drams.
Cb.cms=	.....	cb. ins...							
Cb. ft.=	.....		cb. met's						
Cb.met=	.....			cb.feet	.....	cb. yds			
Cb.yds=	.....				cb.met's				
Fl.drs.=	.....						cb.cms m. lit'r		
1	16.387	0.061 023	0.028 317	35.314	0.764 56	1.307 9	3.696 7	0.270 51	
2	32.774	0.122 05	0.056 634	70.629	1.529 1	2.615 9	7.393 4	0.541 02	
3	49.161	0.183 07	0.084 951	105.94	2.293 7	3.923 8	11.090	0.811 53	
4	65.549	0.244 09	0.113 27	141.26	3.058 2	5.231 8	14.787	1.082 0	
5	81.936	0.305 12	0.141 58	176.57	3.822 8	6.539 7	18.484	1.352 6	
6	98.323	0.366 14	0.169 90	211.89	4.587 4	7.847 6	22.180	1.623 1	
7	114.71	0.427 16	0.198 22	247.20	5.351 9	9.155 6	25.877	1.893 6	
8	131.10	0.488 19	0.226 54	282.52	6.116 5	10.463	29.574	2.164 1	
9	147.48	0.549 21	0.254 85	317.83	6.881 0	11.771	33.270	2.434 6	
10	163.87	0.610 23	0.283 17	353.14	7.645 6	13.079	36.967	2.705 1	

Fl. oz. =	cb.cms								
Cb.cms.=	.....	fl. ounces							
Quarts =	.....		liters						
Liters =	.....			quarts		gallons			
Gallons.=	.....				liters				
Bushels =	.....						hectol'ts		
Hectol't =	.....							bush'ls	
1	29.574	0.033 814	0.946 36	1.056 7	3.785 4	0.264 17	0.352 39	2.837 7	
2	59.147	0.067 628	1.892 7	2.113 4	7.570 9	0.528 34	0.704 79	5.675 5	
3	88.721	0.101 44	2.839 1	3.170 0	11.356	0.792 51	1.057 2	8.513 2	
4	118.29	0.135 26	3.785 4	4.226 7	15.142	1.056 7	1.409 6	11.351	
5	147.87	0.169 07	4.731 8	5.283 4	18.927	1.320 9	1.762 0	14.189	
6	177.44	0.202 88	5.678 2	6.340 1	22.713	1.585 0	2.114 4	17.026	
7	207.02	0.236 70	6.624 5	7.396 8	26.498	1.849 2	2.466 7	19.864	
8	236.59	0.270 51	7.570 9	8.453 5	30.283	2.113 4	2.819 1	22.702	
9	266.16	0.304 32	8.517 2	9.510 1	34.069	2.377 5	3.171 5	25.540	
10	295.74	0.338 14	9.463 6	10.567	37.854	2.641 7	3.523 9	28.377	

VOLUMES. Cubic and Capacity Measures (continued).**Unusual, Special Trade, or Obsolete.**

ap. means apothecary measures; av. means avoirdupois weights; aprx. means approximately.

1 molecule. There are about a million, million, million molecules in a cb. millimeter of air (Woodward).

1 cubic millimeter [mm^3]=0.001 milliliter or cb. centimeter.

1 minim or drop (ap. Brit.)=59.192 2 cb. millimeters= $\frac{1}{20}$ fluid scruple (ap. Brit.)=0.059 192 2 milliliter or cb. centimeter= $\frac{1}{60}$ fluid dram (ap. Brit.). **1 milliliter or cb. centimeter**=16.894 1 minims or drops (ap. Brit.).

1 minim or drop (ap. U. S.)=61.612 cb. millimeters=0.061 612 milliliter or cb. centimeter= $\frac{1}{60}$ fluid dram (ap. U. S.). **1 milliliter or cb. centimeter**=16.230 6 minims or drops (ap. U. S.).

1 milliliter [ml]=1 cb. centimeter, which see above in other table; it equals 0.001 liter.

1 fluid scruple (ap. Brit.)=20. minims (ap. Brit.)=1.183 845 milliliters or cb. centimeters= $\frac{1}{2}$ fluid dram (ap. Brit.)= $\frac{1}{24}$ fluid ounce (ap. Brit.). **1 milliliter or cb. centimeter**=0.844 705 fluid scruple (ap. Brit.).

1 fluid drachm same as fluid dram.

1 fluid dram (ap. Brit.)=60. minims (ap. Brit.)=3.551 534 milliliters or cb. centimeters=3. fluid scruples (ap. Brit.)=0.216 73 cb. inch= $\frac{1}{8}$ fluid ounce (ap. Brit.)= $\frac{1}{160}$ pint (Brit.). **1 cb. centimeter**=0.281 57 fluid dram (ap. Brit.).

1 fluid dram (ap. U. S.)=60. minims (ap. U. S.)=0.225 59 (aprx. $\frac{2}{9}$) cb. inch= $\frac{1}{8}$ fluid ounce (ap. U. S.)= $\frac{1}{128}$ pint (liquid; U. S.)=3.696 71 milliliter or cb. centimeter. **1 cb. centimeter**=0.270 51 fluid dram (ap. U. S.).

1 centiliter [cl]=10. cb. centimeters=0.610 234 cb. inch=0.01 liter.

1 fluid ounce [fl oz] (ap. Brit.)=480. minims (ap. Brit.)=28.412 27 cb. centimeters or milliliters=24. fluid scruples (ap. Brit.)=8. fluid drams (ap. Brit.)=1.733 81 cb. inches=0.960 73 fluid ounce (ap. U. S.)= $\frac{1}{20}$ pint (Brit.)=0.028 412 27 liter. **1 liter**=35.196 fluid ounces (ap. Brit.).

1 fluid ounce [fl oz] (ap. U. S.)=480. minims (ap. U. S.)=29.573 7 cb. centimeters=8. fluid drams (ap. U. S.)=1.804 69 (aprx. $\frac{9}{5}$) cb. inches=1.040 88 fluid ounces (ap. Brit.)= $\frac{1}{16}$ pint (liquid; U. S.)=0.029 573 7 liter. **1 liter**=33.813 8 fluid ounces (ap. U. S.).

1 gill [gi] (liquid; U. S.)=118.295 cb. centimeters=7.218 750 cb. inches=1.182 95 deciliters=0.832 702 4 gill (Brit.)= $\frac{1}{4}$ pint (liquid; U. S.)= $\frac{1}{2}$ quart (liquid; U. S.)=0.118 295 liter. **1 cb. inch**=0.138 528 gill (liquid; U. S.). **1 liter**=8.453 44 gills (liquid; U. S.).

1 gill [gi] (Brit.)=142.061 35 cb. centimeters=8.669 05 cb. inches=1.420 613 5 deciliters=1.200 91 gills (liquid; U. S.)= $\frac{1}{4}$ pint (Brit.)= $\frac{1}{8}$ quart (Brit.)=0.142 061 35 liter. **1 cb. inch**=0.115 352 8 gill (Brit.). **1 liter**=7.039 20 gills (Brit.).

1 pint [pt] (ap. U. S.)=128. fluid drams (ap. U. S.)=16. fluid ounces (ap. U. S.)=0.473 179 liter=same as liquid U. S. pint.

1 pint [pt] (ap. Brit.)=480. fluid scruples (ap. Brit.)=160. fluid drams (ap. Brit.)=20. fluid ounces (ap. Brit.)=0.568 245 4 liter=same as ordinary Brit. pint.

1 millistere=1 cb. decimeter=1 liter.

1 pottle (Brit.)= $\frac{1}{2}$ gallon Brit.

1 board foot=144. cb. inches= $\frac{1}{12}$ cb. foot.

1 gallon [gal] (ap. U. S.), same as ordinary liquid U. S. gallon of 231. cb. inches.

1 gallon [gal.] (wine; old Brit.), same as ordinary liquid, U. S. gallon of 231. cb. inches.

1 gallon (dry; U. S.) (obsolete; term " $\frac{1}{2}$ peck" used instead)=268.802 5 cb. inches=8. pints (dry; U. S.)=4.404 91 liters=4. quarts (dry; U. S.)= $\frac{1}{2}$ peck (U. S.).

1 gallon [gal] (ap. Brit.), same as ordinary Brit. or Imperial gallon.

1 beer gallon (obsolete)=282. cb. inches=8. beer pints=4. beer quarts.

1 decaliter or dekaliter [dkl]=10. liters=1 centistere.

1 centistere=10. cb. decimeters or liters=1 decaliter= $\frac{1}{100}$ stere or cb. meter.

1 gram-molecule of any gas at 0° C. and 760 mm. pressure has a volume of 22 380. cb. centimeters.

1 foot (solid, timber)=1 cb. ft.

1 solid foot=1 cb. ft.

1 hektoliter [hl], same as hectoliter.

1 decistere [ds]=100. cb. decimeters or liters=1 hectoliter= $\frac{1}{10}$ stere or cb. meter.

1 firkin=9. gallons (liquid; U. S.)=7.494 3 gallons (Brit.)=34.068 9 liters= $\frac{1}{4}$ barrel. Of butter=56. pounds (av.).

1 Winchester bushel [bu], same as ordinary bushel in U. S.=2 150.42 cb. inches.

1 struck bushel, same as ordinary bushel in U. S.=2 150.42 cb. inches.

1 heaped bushel= $1\frac{1}{4}$ struck bushels or $1\frac{1}{4}$ ordinary bushels (U. S.).

1 bushel=60 pounds of wheat=56 pounds of corn or rye=48 pounds of barley=32 pounds of oats=60 pounds of peas=42 pounds of buckwheat. (U. S. Customs; legal.)

1 coomb (Brit.)=16. pecks (Brit.)=4. bushels (Brit.)=1.454 708 hectoliters= $\frac{1}{2}$ quarter (Brit.).

1 barrel [bbl], has no legal or fixed value; it varies between 30 and 43 gallons (liquid; U. S.). Barrels should therefore always be gauged. The following are the most usual values, about in the probable order of importance:

1 barrel (liquid; U. S.)=31 $\frac{1}{2}$ gallons (liquid; U. S.)=4.211 0 cb. feet=1.192 4 hectoliters= $\frac{1}{2}$ hogshead.

1 barrel (wine and brandy; Brit.)=31 $\frac{1}{2}$ gallons (Brit.)=1.431 98 hectoliters. Also given as 36 gallons (Brit.).

1 barrel (liquid; U. S.)=31. gallons (liquid; U. S.)=1.173 5 hectoliters.

1 barrel (refined oil)=42. gallons (liquid; U. S.; used by Standard Oil Co.).

1 barrel (flour; U. S.)=3. bushels (U. S.); also given as 3.75 cb. feet; "legal" (?) weight given as 196 pounds (av.).

1 barrel (dry; U. S.)=21 $\frac{1}{2}$ bushels (U. S.)=26.756 cb. feet=7.576 45 hectoliters.

1 barrel (beer; U. S.)=36. beer gallons of 282 cb. inches=1.663 6 hectoliters.

1 barrel (liquid; Penna.)=32. gallons (liquid; U. S.).

1 sack (coal; Brit.)=3 bushels (Brit.)= $\frac{1}{12}$ chaldron.

1 decistere=1 hectoliter=0.1 stere or cb. meter.

1 tierce (liquid; U. S.)=42. gallons (liquid; U. S.)=1.589 9 hectoliters= $\frac{2}{3}$ hogshead (U. S.).

1 tierce (Brit.)=42. gallons (Brit.)=1.909 30 hectoliters= $\frac{2}{3}$ hogshead (Brit.).

1 hogshead [hhd] (beer; U. S. obsolete)=54 beer gallons of 282 cb. inches.

1 hogshead [hhd] (liquid; U. S.)=63. gallons (liquid; U. S.)=2. barrels of 31 $\frac{1}{2}$ gallons (liquid; U. S.)=2.384 8 hectoliters=1 $\frac{1}{2}$ tierces (liquid; U. S.).

1 hogshead [hhd] (Brit.)=63. gallons (Brit.)=2.863 96 hectoliters.

1 quarter [qr] (dry; U. S.)=8. bushels (U. S.)=2.819 1 hectoliters= $\frac{1}{4}$ (aprx.) tun (Brit.).

1 quarter [qr] (Brit.)=8. bushels (Brit.)=2.909 416 hectoliters=2. coombs (Brit.)= $\frac{1}{4}$ (aprx.) tun (Brit.)= $\frac{1}{10}$ last (Brit.).

1 puncheon (liquid; U. S.)=84. gallons (liquid; U. S.)=3.179 76 hectoliters=2. tierces (U. S.).

1 puncheon (Brit.)=84. gallons (Brit.)=3.818 61 hectoliters=2. tierces (Brit.).

1 pipe or butt (liquid; U. S.)=126. gallons (liquid; U. S.)=4.769 6 hectoliters=2. hogsheads (U. S.).

1 pipe or butt (Brit.)=126. gallons (Brit.)=5.727 91 hectoliters=2. hogsheads (Brit.).

1 cord foot (wood)=4×4×1 foot=16. cb. feet=0.453 07 cb. meter or stere= $\frac{1}{8}$ cord.

1 tun (liquid; U. S.)=252. gallons (liquid; U. S.)=9.539 3 hectoliters=6. tierces (liquid; U. S.)=4. hogsheads (U. S.)=3. puncheons (U. S.)=2. pipes or butts.

1 tun (Brit.)=252. gallons (Brit.)=11.455 8 hectoliters=6. tierces (Brit.)=4. hogsheads (Brit.)=3. puncheons (Brit.)=2. pipes or butts (Brit.).

- 1 **perch** (masonry) = $16\frac{1}{2} \times 1\frac{1}{2} \times 1$ foot = $24\frac{3}{4}$ cb. feet (generally 25 cb. feet, sometimes 22 cb. feet) = 0.916 67 cb. yard = 0.700 85 stere or cb. meter.
- 1 **solid yard** = 1 cb. yard.
- 1 **stere** [s] = 1 cb. meter, which see above in other table.
- 1 **kiloliter** [kl] = 1 000. liters = 10. hectoliters = 1 cb. meter or stere.
- 1 **gross ton** (2240 pounds av.) *displacement of water* = 35.881 3 cb. feet = 1.328 93 cb. yards = 1.016 05 cb. meters.
- 1 **shipping ton** (for cargo; U. S.) = 40. cb. feet = 32.142 6 bushels (U. S.) = 31.145 2 bushels (Brit.) = 11.326 8 hectoliters = 1.132 68 cb. meters.
- 1 **shipping ton** (for cargo; Brit.) = 42. cb. feet = 33.749 7 bushels (U. S.) = 32.702 5 bushels (Brit.) = 11.893 1 hectoliters = 1.189 31 cb. meters.
- 1 **chaldron** (dry; U. S.) = 44.800 6 cb. feet = 36. bushels (U. S.) = 12.686 1 hectoliters.
- 1 **chaldron** (coal; Brit.) = 12. sacks = 36. bushels (Brit.) = 58.658 cb. feet; weight 3 136. pounds (av.).
- 1 **chaldron** (Canada) = 58.64 cb. feet or about 45 bushels (Brit.); stated also as 25.64 cb. feet or about 20 bushels (Brit.).
- 1 **chaldron** (Newcastle) weight 5 936. pounds (presumably coal).
- 1 **wey** (Brit.) = 51.372 4 cb. feet = 40. bushels (Brit.) = 5. quarters (Brit.) = $\frac{1}{2}$ last (Brit.).
- 1 **register ton** (shipping; for whole vessels) = 100. cb. feet = 2.831 7 cb. meters.
- 1 **last** (Brit.) = 102.745 cb. feet = 80. bushels (Brit.) = 10. quarters (Brit.) = 2. weys (Brit.).
- 1 **cord** [c] (wood) = $4 \times 4 \times 8$ feet = 128. cb. feet = 8. cord feet = 3.624 58 cb. meters or stere. 1 stere or cb. meter = 0.275 894 cord.
- 1 **toise** (Canada) = $261\frac{1}{2}$ cb. ft. = 9.685 18 cb. yds. = 7.404 90 cb. meters.
- 1 **rod** (brickwork; Brit.) = $16\frac{1}{2}$ feet square $\times$ 14. inches = $272\frac{1}{4}$ sq. feet of 14. inch wall; conventionally 272. sq. feet of 14. inch wall = $317\frac{1}{3}$ cb. feet = 8.985 9 cb. meters.
- 1 **rod** (engineering works; Brit.) = 306. cb. ft. = $11\frac{1}{3}$ cb. yards = 8.665 cb. meters.
- 1 **myrialiter** or **myrioliter** = 10 000. liters = 100. hectoliters = 10. cb. meters or steres = 1 decastere.
- 1 **decastere** or **dekastere** [dks] = 100. hectoliters = 10. cb. meters or steres = 1 myrialiter.
- 1 **hectostere** or **hektostere** [hks] = 100. steres or cb. meters.
- 1 **acre-foot** (irrigation) = 325 851. gallons = 43 560. cb. feet = 1 613.33 cb. yards = 1 233.49 cb. meters.

VOLUMES. Cubic and Capacity Measures (concluded).

Foreign.

These are mostly obsolete, as the metric system is now used in most foreign countries. The British measures are included among the U. S. measures, being very nearly, and sometimes quite, the same. The translated terms are merely synonymous, and not the exact equivalents.

Germany. Prussian. 1 Fuder = 4 Oxhoft of $1\frac{1}{2}$ Ohm of 2 Eimer (bucket) of 2 Anker of 30 Quart (Prussian). 1 Wispel = 6 Tonne (tun) of 4 Scheffel of 16 Metzen of 3 Quart (Prussian). 1 Quart (Prussian) = 64 cub. Zoll = $\frac{1}{27}$ cub. Fuss = 1.145 03 liters; 1 Wispel = 13.191 hectoliters; 1 Tonne = 2.198 46 hectoliters; 1 Scheffel = 0.549 61 hectoliter. 1 Schacht-ruthe = 144. cub. Fuss = 4.451 9 cub. meters. 1 Klafter = 108 cub. Fuss = 3.338 9 cub. meters.

The following values are given by Nystrom; they are in cubic inches. For liquid measures: 1 Stubgen in Bremen = 194.5, in Hamburg 221, in Hanover 231. For dry measures: 1 Scheffel in Berlin 3 180, in Bremen 4 339, in Hamburg 6 426. 1 Hanover Malter = 6 868.

France. "Old Measures" (système ancien) used prior to 1812. 1 muid (hogshead) = 2 feuilletes of 2 quartants of 9 setiers or veltes of 4 pots of 2 pintes (pint, though more nearly equal to a quart) of 2 chopines of 2 demi-setiers of 2 possons of 2 demi-possons of 2 roquilles (gill). 1 pinte (ancienne) = 0.931 32 liter.

“New measures” (système usuelle) used from 1812 to 1840. 1 boisseau = 2.751 2 gallons (Brit.); 1 litron (old liter) = 1.760 8 pints (Brit.); hence it seems that 1 boisseau = $12\frac{1}{2}$ litrons; 1 pinte = 1 liter.

The following values are given by Nystrom; they are in cubic inches. For liquid measures: 1 Bordeaux barrique = 14 033. For dry measures: 1 Marseilles charge = 9 411.

Austria. Liquid measures: 1 Eimer = 40 Maass of 4 Seidel of 2 Piff. 1 Eimer = 56.589 liters; 1 Maass = 1.414 724 liters = 0.044 8 cub. Fuss. Dry measures: 1 Mut or Muth = 30 Metzen of 16 Maassel of 4 Futtermaassel of 2 Becher. 1 Metze = 61.486 82 liters = 1.947 1 cub. Fuss.

The following values are given by Nystrom; they are in cubic inches. For liquid measures: 1 Hungarian Eimer 4 474; 1 Trieste Orne = 4 007; 1 Vienna Eimer = 3 452; 1 Vienna Maass 86.33. For dry measures: 1 Trieste Stari 4 521; 1 Vienna Metzen 3 753.

Sweden. 1 am = 4 anker of 15 kannen of 2 stop. 1 am = 157.030 liters; 1 kanne = 2.617 liters = 100 cub. decimal tum. For grain: 1 tonne = 2 spon of 16 koppen. 1 tonne = 56 kannen = 146.565 liters. According to Nystrom 1 Swedish eimer = 4 794 cub. inches; 1 kanna = 159.57 cub. inches; 1 tunna = 8 940 cub. inches.

Russia. 1 tschetwert = 2 osmini of 2 pajok of 2 tschetwerik of 4 tschetwerka of 2 garnez. 1 tschetwert = 209.9 liters; 1 tschetwerik = 26.209 liters; 1 tschetwerka = 6.552 2 liters; 1 garnez = 3.276 1 liters. 1 botschka (barrel) = 40 wedro of 10 kruschky or stoof of 10 tscharky. 1 kruschky = 1.228 5 liters. According to Nystrom 1 Russian weddras = 752 cub. inches; 1 kunkas = 94 cub. inches; 1 Riga loop = 3 978 cub. inches; 1 chetwert = 12 448. cub. inches.

Spain. 1 cantara of wine (castile) = 4.263 gallons (liquid; U. S.); in Havana 4.1 gallons. 1 fanega of corn = 1.599 14 bushels (U. S.). According to Nystrom 1 azumbras = 22.5 cub. inches; 1 quartellos = 30.5 cub. inches; 1 catrize = 41 269. cub. inches; 1 Malaga fanaga = 3 783. cub. inches.

Japan. 1 koku = 10 to; 1 to = 10 sho of 10 go of 10 seki. 1 koku = 180.39 liters = 47.66 gallons (U. S.). 1 liter = 0.005 54 koku. 1 gallon (U. S.) = 0.021 0 koku.

Miscellaneous. The following are given in Nystrom's Mechanics in cubic inches. For liquid measures: Amsterdam Anker = 2 331; stoop 146; Copenhagen Anker 2 355; Antwerp stoop 194. Florence oil barille 1 946, wine barille 2 427; Genoa wine barille 4 530, pinte 90.5; Leghorn oil barille 1 942; Naples wine barille 2 544, oil stajo 1 133; Rome wine barille 2 560, oil barille 2 240, boccali 80; Sicily oil caffiri 662; Malta caffiri 1 270; Venice Secchio 628. Lisbon almude 1 040; Oporto almude 1 555; Constantinople almude 319. Geneva setier 2 760. Canaries arrobas 949. Scotland pint = 103.5. Tripoli mattari 1 376. Tunis oil mattari 1 157.

For dry measures: Amsterdam mudde 6 596, sack 4 947; Rotterdam sach 6 361; Copenhagen toende 8 489; Antwerp viertel 4 705. Florence stari 1 449; Genoa mina 7 382; Leghorn stajo 1 501, sacco 4 503; Milan moggi 8 444; Naples temoli 3 122; Rome rubbio 16 904, quarti 4 226; Sardinia starelli 2 988; Sicily salme gros 21 014, salme generale 16 886; Malta salme 16 930; Corsica stajo 6 014; Venice stajo 4 945. Lisbon alquiere 817, fanega 3 268; Madeira alquiere 684; Oporto alquiere 1 051. Alexandria rebele 9 587, kislos 10 418; Constantinople kislos 2 023; Smyrna kislos 2 141. Algiers tarrie 1 219. Tripoli caffiri 19 780; Tunis caffiri 21 855. Candia charge 9 288. Greece medimni 2 390. Persia artaba 4 013. Poland zorzec 3 120. Geneva coupes 4 739. Scotland firlot 2 197.

WEIGHTS or MASSES.

The fundamental standard of mass (commonly called weight) of the United States is the International Kilogram, a cylindrical mass of metal made of 90% platinum and 10% iridium, and preserved at the International Bureau of Weights and Measures, near Paris. Copies of the International Kilogram are possessed by each of the 20 countries contributing to the support of the International Bureau of Weights and Measures, and these copies are known as National Prototypes. The United States possesses two of these standards, whose values in terms of the International Kilogram are known with the greatest accuracy. One of the kilograms known as No. 4 is used as a working standard and the other, No. 20, is kept under seal and only used to check No. 4. One of the objects for the maintenance of the International Bureau of Weights and Measures is to provide for the recomparison at regular intervals of the various National Prototypes with the International Kilogram, thus insuring the use of the same standard throughout the world.

According to the Act of Congress of July 28, 1866, which was the first general legislation upon the subject of fixing the standard of weights and measures, the pound is to be derived from the kilogram. This act defined the relation $1 \text{ kilogram} = 2.2046 \text{ avoirdupois pounds}$; but this has since been changed to the more accurate value, $1 \text{ kilogram} = 15\,432.356\,39 \text{ grains}$, which corresponds to $2.204\,622\,34 \text{ avoirdupois pounds}$, or $1 \text{ avoirdupois pound} = 453.592\,427\,7 \text{ grains}$. This value is the one now used by the National Bureau of Standards in Washington and the avoirdupois pounds, ounces, grains, etc., in common use now in this country are *derived from the kilogram* according to this relation, and are consequently fixed and definite units. In this country the relation between the pound and the kilogram is therefore no longer to be determined by measurement, as is often supposed, but is fixed definitely by precise definition.

The troy pound was definitely adopted by Congress in 1828 for coinage purposes and was supposed to be an exact copy of the British troy pound; formerly the avoirdupois pound was derived from this according to the relation $1 \text{ avoirdupois pound} = 7000/5760 \text{ troy pound}$; this relation is still correct, but in this country both the troy and the avoirdupois pounds as now standardized by the Government are derived from the kilogram as stated above, and hence both values are fixed definitely. The old troy pound, "although totally unfit for such purpose," is the legal standard for coinage purposes in this country; according to the National Bureau of Standards, the troy pound of the Mint, and the troy pound of that Bureau (based on the kilogram) are the same.

The kilogram was originally intended to be the mass of a cubic decimeter or liter of pure water at the temperature of its maximum density. The present International Prototype Kilogram is an exact copy of the original kilogram of the archives, which when made was supposed to be equal to the weight of one cubic decimeter of water. It is a certain mass of platinum-iridium. The determination of the precise relation of this adopted kilogram to the mass of a cubic decimeter of water is now in progress, and it may be several years before the final results are announced. The results thus far indicate that the kilogram is heavier than it would be according to the original definition by about 25 milligrams, or about 25 parts in 1 000 000. The present kilogram, however, is definite, and the result of such a discrepancy would make the liter, which is the volume of a kilogram of water, very slightly larger than the cubic decimeter by about 25 parts in 1 000 000. The question of correcting the kilogram to agree with its original theoretical definition may be considered when the determination now being made at the International Bureau has been completed. For all but the most refined measurements, however, this slight discrepancy is absolutely negligible. The National Bureau of Standards has for the present assumed that the liter and the cubic decimeter are equivalent; this identity is assumed also in all the tables in this book.

The relation, legalized in Great Britain in 1898, between the avoirdupois pound and the kilogram, is precisely the same as that in this country, hence the pounds are exactly the same in both countries. All the avoirdupois, troy and apothecary weights are therefore also the same in the United States and in Great Britain.

The metric weights are now in use everywhere for all accurate scientific measurements. In this country they are coming into more general use; chemists use them entirely. The **avoirdupois weights** (abbreviation av.) are used for most purposes, including merchandise in general. The **troy weights** are used for weighing gold, silver, etc.; they are used by the U. S. Mint; quantities, even much larger than an ounce, are usually stated in ounces and not in pounds. In the **apothecary weights** (abbreviation ap.) only the grain, scruple, and dram are in general use in this country; the ounce is used only when called for in prescriptions; apothecaries almost always use the avoirdupois pound and ounce. The apothecary ounce and pound are the same as the troy. The **grain** is the same in all three systems.

No fixed rules can be given concerning the distinction between the use of the **short or net ton** of 2 000 lbs. and the **long or gross ton** of 2 240 lbs., but the following general rules may serve as a guide. The long ton seems to be the only official one; section 2951 of the Revised Statutes of the U. S., 2d Ed., 1878, Collection of Duties upon Imports, Chapter 6, says that by the word "ton" in that chapter is meant 2 240 pounds. With freight on railroads, a ton of 2 240 pounds seems to be generally used. In the iron and steel trades, pig iron, steel rails, and iron ore are bought and sold by the ton of 2 240 pounds. Coal seems to be weighed in long tons also; coke, however, is weighed in short tons of 2 000 pounds. The short ton of 2 000 pounds seems to be in general use for weighing chemical products, or in general for the more expensive products; but in shipping them on railroads the ton of 2 240 pounds is often used. The short ton seems to be in general use also in traction engineering calculations.

What are popularly termed **weights** should more correctly be called **masses**, but for all practical purposes the two terms are the same. The mass of a body is the same anywhere in the universe, but its weight depends on the attraction of gravitation. The mass of a body is most conveniently measured by its weight, and if the attraction of gravitation is the same (and it varies but slightly at different parts of earth) the weight will be a correct measure of the mass. With the usual beam balance, the comparison of two masses by means of their weights is absolutely exact and quite independent of the value of gravity, which acts equally on both; but with spring scales the same mass may have slightly different weights, depending on the force of gravity.

When **weights** are considered as such, and not as masses, they are **forces** and have the dimensions of forces. The reduction factors in the following table are correct whether the units are considered as masses or as forces. The reduction factors between them and the true units of force (such as dyne and poundal) are given in a separate table of forces so as to avoid confusion. See also note under Forces and under Acceleration.

WEIGHTS or MASSES. (See also FORCES.) Usual.

** Accepted by the National Bureau of Standards.

* Checked by L. A. Fischer, Asst. Phys. National Bureau of Standards.
av. means avoirdupois. Aprx. means within 2%.

		Logarithm
1 milligram [mg]	= 0.1 centigram.....	1.000 0000
"	= 0.015 432 4* grain. Aprx. $\frac{2}{13} \div 10$	2.188 4322
"	= 0.001 gram.....	3.000 0000
1 centigram [cg]	= 10. milligrams.....	1.000 0000
"	= 0.154 324* grain. Aprx. $\frac{2}{13}$	1.188 4322
"	= 0.01 gram.....	2.000 0000
1 grain [gr]	= same in avoirdupois, troy, or apothecary weights.	
"	= 64.798 9* milligrams. Aprx. 65.....	1.811 5678
"	= 6.479 89* centigrams. Aprx. $6\frac{1}{2}$	0.811 5678
"	= 0.064 798 9* gram. Aprx. $1\frac{1}{2} \div 100$	2.811 5678
"	= 0.002 285 71* ounce (av.). Aprx. $\frac{1}{4} \div 1\ 000$	3.359 0219
1 decigram [dg]	= 1.543 24* grains. Aprx. $1\frac{1}{4}$	0.188 4322
"	= 0.1 gram.....	1.000 0000

1 gram [g]=	1 000.	milligrams.	3.000 0000
" =	100.	centigrams.	2.000 0000
" =	15.432 356 39**	grains. Aprx. $15\frac{1}{2}$.	1.188 4322
" =	0.035 274 0*	ounce (av.). Aprx. $\frac{1}{2} \div 100$.	2.547 4541
" =	0.032 150 7*	ounce (troy). Aprx. $32 \div 1\ 000$.	2.507 1910
" =	0.002 204 62*	pound (av.). Aprx. $22 \div 10\ 000$.	3.343 3342
" =	0.001	kilogram.	3.000 0000
1 ounce [oz] (av.)=	2 834.95*	centigrams. Aprx. $\frac{3}{4} \times 10\ 000$.	3 452 5459
" =	437.500*	grains. Aprx. $1\frac{3}{4} \times 100$.	2.640 9781
" =	28.349 5*	grams. Aprx. $\frac{3}{4} \times 100$.	1.452 5459
" =	16.	drams (av.).	1.204 1200
" =	0.911 458*	ounce (troy). Aprx. $1\frac{1}{11}$.	1.959 7369
" =	0.062 500*	pound (av.) or $\frac{1}{80}$.	2.795 8800
" =	0.028 349 5*	kilogram. Aprx. $\frac{3}{4} \div 10$.	2.452 5459
1 pound [lb] (av.)=	7 000.**	grains.	3.845 0980
" =	453.592 427 7**	grams. Aprx. $\frac{1}{2} \times 100$.	2.656 6658
" =	256.	drams (av.).	2.408 2400
" =	16.	ounces (av.).	1.204 1200
" =	14.583 3*	oz. (troy). Aprx. $\frac{1}{4} \times 100$.	1.163 8569
" =	0.453 592 4*	kilogram. Aprx. $\frac{1}{2} \div 10$.	1.656 6658
1 kilogram or kilo [kg]:			
= 15 432.356 39**	grains. Aprx. $3\frac{1}{2} \times 1\ 000$.		4.188 4322
=	1 000.	grams.	3.000 0000
=	35.274 0*	ounces (av.). Aprx. $\frac{1}{2} \times 10$.	1.547 4541
=	32.150 7*	ounces (troy). Aprx. 32.	1.507 1910
=	2.204 62*	pounds (av.). Aprx. $2\frac{1}{16}$.	0.343 3342
=	0.022 046 2*	hundredweight (sh.). Aprx. $22 \div 1\ 000$.	2.343 3342
=	0.019 684 1*	hundredweight (long). Aprx. $2 \div 100$.	2.294 1162
=	0.001 102 31*	short or net ton. Aprx. $\frac{1}{20} \div 100$.	3.042 3042
=	0.001	metric ton.	3.000 0000
=	0.000 984 206	long or gross ton. Aprx. $1 \div 1\ 000$.	4.993 0862
1 hundredweight [cwt] (short):			
=	100.	pounds (av.).	2.000 0000
=	45.359 24*	kilograms. Aprx. $\frac{1}{2} \times 10$.	1.656 6658
=	0.892 857*	hundredweight (long). Aprx. $\frac{1}{10}$.	1.950 7820
=	0.05	short or net ton.	2.698 9700
=	0.045 359 24*	metric ton. Aprx. $\frac{1}{22}$.	2.656 6658
=	0.044 642 9*	long or gross ton. Aprx. $\frac{1}{2} \div 100$.	2.649 7520
1 hundredweight [cwt] (long):			
=	112.	pounds (av.). Aprx. $\frac{1}{10} \times 1\ 000$.	2.049 2180
=	50.802 4*	kilograms. Aprx. 50.	1.705 8838
=	1.120 00*	hundredweights (short). Aprx. 1% .	0.049 2180
=	0.056 000*	short or net ton. Aprx. $\frac{1}{20} \div 10$.	2.748 1880
=	0.050 802 4*	metric ton. Aprx. $\frac{1}{20}$.	2.705 8838
=	0.05	long or gross ton or $\frac{1}{20}$.	2.698 9700
1 short or net ton [tn]:			
=	2 000.	pounds (av.).	3.301 0300
=	907.185*	kilograms. Aprx. 900.	2.957 6958
=	20.	hundredweights (short).	1.301 0300
=	17.857 1*	hundredweights (long). Aprx. $\frac{9}{10} \times 10$.	1.251 8120
=	0.907 185*	metric ton. Aprx. subtract $\frac{1}{10}$.	1.957 6958
=	0.892 857*	long or gross ton. Aprx. subtract $\frac{1}{10}$.	1.950 7820
1 metric ton, tonne, tonneau, millier, or bar [t]:			
=	2 204.62*	pounds (av.). Aprx. 22×100 .	3.343 3342
=	1 000.	kilograms.	3.000 0000
=	22.046 2*	hundredweights (short). Aprx. 22.	1.343 3342
=	19.684 1*	hundredweights (long). Aprx. 20.	1.294 1162
=	1.102 31*	short or net tons. Aprx. add $\frac{1}{10}$.	0.042 3042
=	0.984 206*	long or gross ton. Aprx. 1.	1.993 0862
1 long or gross ton [tn]:			
=	2 240	pounds (av.). Aprx. 22×100 .	3.350 2480
=	1 016.05*	kilograms. Aprx. 1 000.	3.006 9138
=	22.400 0*	hundredweights (short). Aprx. 22.	1.350 2480
=	20.	hundredweights (long).	1.301 0300
=	1.12	short or net tons. Aprx. 1% .	0.049 2180
=	1.016 05*	metric tons. Aprx. 1.	0.006 9138

Conversion Tables for Weights.

Note.—By pounds and ounces are meant avoirdupois pounds and ounces.

Grains =	mlgrs										
Mil'grs =	....	grains									
Ounces =	....		gram								
Grams =	....			ounces							
Pounds =	....				klgrms						
Klgms =	....					pound					
Sh. ton =	....						met. tons				
Lg. ton =	....							met. tons			
Mt. ton =	....							shrt tons	....	long tons	
1	64.799	0.015 432	28.350	0.035 274	0.453 59	2.204 6	0.907	1.102	1.016	0.984	
2	129.00	0.030 865	56.699	0.070 548	0.907 18	4.409 2	1.814	2.205	2.032	1.968	
3	194.40	0.046 297	85.049	0.105 82	1.360 8	6.613 9	2.722	3.307	3.048	2.953	
4	259.20	0.061 730	113.40	0.141 10	1.814 4	8.818 5	3.629	4.409	4.064	3.937	
5	323.99	0.077 162	141.75	0.176 37	2.268 0	11.023	4.536	5.512	5.080	4.921	
6	388.79	0.092 594	170.10	0.211 64	2.721 6	13.228	5.443	6.614	6.096	5.905	
7	453.59	0.108 03	198.45	0.246 92	3.175 1	15.432	6.350	7.716	7.112	6.889	
8	518.39	0.123 46	226.80	0.282 19	3.628 7	17.637	7.257	8.818	8.128	7.874	
9	583.19	0.138 89	255.15	0.317 47	4.082 3	19.842	8.165	9.921	9.144	8.857	
10	647.99	0.154 32	283.50	0.352 74	4.535 9	22.046	9.072	11.02	10.16	9.842	

WEIGHTS or MASSES (continued). Unusual, Special Trade, or Obsolete.

av. means avoirdupois weight; ap. means apothecary weight; aprx. means approximately.

0.001 milligram [*r*] (has no name, symbol used instead) = 0.000 015 432 4 grains.

1 jeweller's grain = $\frac{1}{4}$ carat (diamond) of various weights.

1 carat (diamond) = 4. jeweller's grains = (according to Streeter) in U. S. 205.500 milligrams or 3.171 4 grains, and in England 205.409 milligrams or 3.170 0 grains; other authorities give 3.168, 3.18, and 3.2 grains in U. S., and 3.17 in England. For values in other countries see below under Foreign Weights.

1 scruple [$\mathfrak{S}$] (ap.) = 20. grains = 1.295 978 (aprx. $\frac{9}{10}$) grams = $\frac{1}{3}$ dram (ap.) = $\frac{1}{24}$ ounce (troy or ap.). 1 gram = 0.771 618 (aprx. $\frac{7}{10}$) scruple.

1 pennyweight [dwt] (troy) = 24. grains = 1.555 17 (aprx. $\frac{11}{10}$) grams = $\frac{1}{20}$ ounce (troy or ap.). 1 gram = 0.643 015 (aprx. $\frac{7}{11}$) pennyweight.

1 drachm, same as dram.

1 dram (av.) = $27\frac{1}{32}$ or 27.343 75 (aprx. $27\frac{1}{3}$) grains = 1.771 85 (aprx. $\frac{7}{4}$) grams = 0.455 729 (aprx. $\frac{5}{11}$) drams (ap.) = $\frac{1}{16}$ ounce (av.). 1 gram = 0.564 383 (aprx. $\frac{4}{7}$) dram (av.).

1 dram [$\mathfrak{D}$] (ap.) = 60. grains = 3.887 934 grams = 3. scruples = 2.194 29 (aprx. $\frac{11}{10}$) drams (av.) = $\frac{1}{8}$ ounce (ap.). 1 gram = 0.257 206 drams (ap.).

1 decagram or dekagram [dkg] = 154.323 6 grains = 10. grams = 0.352 74 ounce (av.).

1 ounce (troy, silk) = 360. grains = 23.327 6 grams.

1 ounce [oz] (troy) (used chiefly for gold and silver) = 480. grains = 31.103 5 grams = 20. pennyweights = 1.097 14 (aprx. $\frac{11}{10}$) ounces (av.) = 1 ounce (ap.) = $\frac{1}{12}$ or 0.083 333 3 pound (troy or ap.) = 0.068 571 4 pound (av.). 1 gram = 0.032 150 7 ounce (troy). 1 ounce (av.) = 0.911 458 (aprx. $\frac{10}{11}$) ounce (troy). 1 pound (av.) = 14.583 3 (aprx. $\frac{100}{11}$) ounces (troy). 1 kilogram = 32.150 7 ounces (troy).

1 ounce [$\mathfrak{Z}$] (ap.) (used only in prescriptions) = 480. grains = 31.103 5 grams = 24. scruples = 8. drams (ap.) = 1.097 14 (aprx. $\frac{11}{10}$) ounces (av.) = 1 ounce (troy) = $\frac{1}{12}$ or 0.083 333 3 pound (ap. or troy) = 0.068 571 4 pound (av.). 1 gram = 0.032 150 7 ounce (ap.). 1 ounce (av.) = 0.911 458 (aprx. $\frac{10}{11}$) ounce (ap.). 1 pound (av.) = 14.583 3 ounces (ap.). 1 kilogram = 32.150 7 ounces (ap.).

- 1 **hectogram** [hg]=100. grams=3.527 40 ounces (av.).
 1 **pound** (troy) (seldom used; troy ounces used instead)=5 760. grains=240. pennyweights=12. ounces (troy or ap.)=1 pound (ap.)= $\frac{5760}{7000}$ or 0.822 857 (aprx. $\frac{5}{6}$) pound (av.)=0.373 242 (aprx. $\frac{3}{8}$) kilogram. 1 pound (av.)= $\frac{7000}{5760}$ or 1.215 28 (aprx. $\frac{5}{6}$) pounds (troy). 1 kilogram=2.679 23 pounds (troy).
 1 **mint pound** (U. S.), same as troy pound.
 1 **pound** (troy, silk)=16. ounces (troy, silk)=5 760. grains=1 pound (troy).
 1 **pound** (ap.) (obsolete) = 5 760. grains = 288. scruples = 96. drams (ap.)=12. ounces (ap. or troy)=1 pound (troy)= $\frac{5760}{7000}$ or 0.822 857 (aprx. $\frac{5}{6}$) pound (av.)=0.373 242 (aprx. $\frac{3}{8}$) kilogram. 1 pound (av.)= $\frac{7000}{5760}$ or 1.215 28 (aprx. $\frac{5}{6}$) pounds (ap.). 1 kilogram=2.679 23 pounds (ap.).
 1 **stone** (Brit.)=14. pounds (av.)=6.350 29 kilograms.
 1 **myriagram**=10 000. grams=22.046 2 pounds (av.)=10. kilograms.
 1 **quarter** [qr] (short) = 25. pounds (av.) = 11.339 8 kilograms = $\frac{1}{4}$ hundredweight (short).
 1 **quarter** [qr] (long)=28. pounds (av.)=12.700 6 kilograms= $\frac{1}{4}$ hundredweight (long).
 1 **firkin** (butter)=56. pounds (av.) (really a capacity measure).
 1 **bushel** (salt)=70. pounds (av.) (really a capacity measure).
 1 **quintal** (av.)=100. pounds (av.)=45.359 24 kilograms=1 hundredweight (short).
 1 **barrel** of flour ("legal"?)=196. pounds (av.).
 1 **barrel** of beef or pork=200. pounds (av.).
 1 **quintal** (metric)=100. kilograms=220.462 pounds (av.).
 1 **pig** (metal)=301. pounds (av.)=21 $\frac{1}{2}$ stones.
 1 **fother** (iron, lead, etc.)=2 408. pounds (av.)=172. stones=8. pigs.
 1 **bloom ton**=1 $\frac{1}{10}$ long tons=2 464. lbs.

Relative Weights (used in chemistry).

- 1 **millimol**=0.001 mol or gram molecule.
 1 **mol** or **mole**=1 gram molecule, which see below.
 1 **gram molecule**=as many grams of a substance as is represented numerically by its molecular weight. A gram molecule of any gas at 0° C. and 760 mm pressure occupies a volume of 22 380. cubic centimeters.
 1 **kilogram molecule**=1 000. gram molecules.
 1 **gramatom**=as many grams of an elemental substance as is represented numerically by its atomic weight.

WEIGHTS OR MASSES (concluded). Foreign.

These are mostly obsolete, as the metric system is now used in most foreign countries. The British measures are included among the U. S. measures, being very nearly, and sometimes quite, the same. The translated terms are merely synonymous, and not the exact equivalents.

Germany. Prussia. To 1839 inclusive: 1 Centner (hundredweight)=110 Pfund (pound) of 32 Loth of 4 Quentchen. 1 Pfund=0.467 711 kilogram. From 1840 for customs and from 1858 for trade: 1 Centner or Z.C.=100 Pfund (pound) of 30 Loth of 10 Quentchen of 10 Cent or zent of 10 Kern or Korn (grain); 1 Pfund=0.5 kilogram. Apothecaries weight: 1 Pfund=12 Unzen (ounces) of 8 Drachmen of 3 Skrupel of 20 Gran (grain) (signs the same as in U. S. apoth. measure; values slightly smaller); 1 Pfund=0.350 783 kilogram (see also under Baden); 1 Schiffslast (shipping weight)=40 Centner=2 000 kilograms. 1 carat (diamond) in Berlin 205.440, in Frankfort o. M. 205.770, and in Leipsic 205.000 milligrams (Streeter).

Bavaria. 1 Pfund (pound)=32 Loth of 4 Quentchen; 1 Pfund=0.560 0 kilogram.

Saxony. 1 Pfund (pound)=4 Pfenniggewicht (pennyweight) of 2 Hellergewicht; 1 Pfund=0.467 6 kilogram.

Württemberg. To 1850: 1 Pfund (pound)=32 Loth of 4 Quentchen of 4 Richtpfennig; 1 Pfund=0.467 7 kilogram. Since 1850 like in Baden.

Baden. 1 Pfund (pound)=2 Mark of 2 Vierlingen of 4 Unzen (ounces); or 1 Pfund=10 Zehnlingen of 10 Centas of 10 Dekas of 10 As; or 1 Pfund=

32 Loth of 4 Quentchen; 1 Pfund=0.5 kilogram. (Another authority states that these are Prussian.)

Hanover. 1 Pfund=0.469 6 kilogram.

The following additional values of various German pounds in pounds avoirdupois are given by Nystrom: Berlin 1.033; Bremen 1.100; Brunswick 1.029; Hamburg 1.068; Hanover 1.073; Leipsic 1.029.

France. Old weights (*système ancien* or *poid de marc*) used prior to 1812. 1 millier (ton)=10 quintaux of 100 livres (pounds); 1 livre (pound)=2 marcs of 8 onces (ounces) of 8 gros (drams) of 3 deniers (scruples) of 24 grains; 1 livre=0.489 506 kilogram. "Usual" weights (*système usuel*) used from 1812 to 1840: 1 livre (pound)=0.5 kilogram. Apothecaries' weights: 1 livre (romain) (pound)=12 onces (ounces) of 8 dragmes (drams) of 3 scrupules (scruples) of 20 grains; 1 livre romain=0.75 livre de marc=0.367 129 kilogram. Nystrom gives 1 Lyons pound (silk)=1.012 2 pounds av. Streeter gives 1 carat (diamond)=205.500 milligrams.

Austria. 1 Centner (hundredweight)=100 Pfund (pound) of 32 Loth of 4 Quentchen of 4 Pfennig; 1 Pfund=0.560 01 or 0.560 06 kilogram. 1 Schiffstone (shipping ton)=20 Centner=1 120.12 kilograms. 1 Metercentner (metric hundredweight)=100 kilograms. Nystrom gives 1 Vienna pound=1.235 pounds av. Streeter gives 1 carat (diamond) in Vienna=206.130 milligrams.

Sweden. 1 centner=100 schalpfund or skalpund or mark (pound) of 32 lod of 4 kvintin of 69 $\frac{1}{8}$ ass; or 1 skalpund=100 korn of 100 art; 1 skalpund=100 korn of 100 art; 1 skalpund=0.425 1 or 0.425 339 5 kilogram. 1 schiffspund (shipping pound)=20 liespund=400 skalpund. Nystrom gives 1 Swedish pound=0.937 5 pound av.; 1 miner's pound=0.828 6 pound av.

Russia. 1 pfund (pound)=32 loth of 3 solotnick of 96 doli; 1 pfund=0.409 512 or 0.409 531 kilogram. Shipping weights: 1 berkowitz=10 pud or pood of 40 pfund (pounds); 1 berkowitz=163.81 kilograms. Nystrom gives 1 Russian pound=0.902 pounds av.; 1 Warsaw pound=0.891 pound av.

Switzerland. Like Baden except that 1 Pfund=32 Loth of 16 Ungen. Nystrom gives 1 Geneva pound, heavy,=1.214 pounds av.

Holland. 1 Amsterdam or Rotterdam pound=1.089 pounds av. 1 carat (diamond) in Amsterdam=205.700 milligrams.

Spain. 1 marce or mark=50 castellanos of 8 tomines of 12 Spanish gold grains. 1 marco=0.507 6 pounds av. in Spain=about 0.506 5 pounds av. in South America; other values up to 0.54; 1 castellano=71.07 to 71.04 grains (U. S.). 1 tonelada (ton)=20 quintal (hundredweight) of 4 arroba (quarters) of 25 libra (pounds); 1 tonelada of Castile=2 032.2 pounds avoirdupois; 1 libra=0.461 0 kilogram=1.016 1 pounds av.; 1 arroba of Castile or Madrid=25.402 5 pounds av.; it has various values in different parts of Spain. Nystrom gives 1 Barcelona pound=0.888 1 pound avoirdupois. Streeter gives 1 carat (diamond)=205.393 milligram.

Italy. Nystrom gives the following values in pounds avoirdupois: Bologna pound 0.798; Corsica pound 0.759; Florence pound 0.749; Genoa pound 1.077; Leghorn pound 0.749; Naples Rottoli 1.964; Rome pound 0.748; Sicily pound 0.700; Venice pound, heavy, 1.055, light, 0.667. Streeter gives 1 carat (diamond) in Florence=195.200, in Leghorn 215.990 milligrams.

Japan. 1 kwan=1 000 momme of 10 fun. 1 kwan=6 $\frac{1}{2}$ (aprx.) kin of 160 momme. 1 kwan=3.76 kilograms=8.29 pounds (av.). 1 kilogram=0.266 kwan. 1 pound=0.121 kwan.

Miscellaneous. Nystrom gives the following values which have here been reduced to pounds avoirdupois: Antwerp pound 1.034; Copenhagen pound 1.101; Madeira pound 0.698; Tangiers pound 1.061; Cairo rottoli 0.952; Alexandria rottoli 0.935; Algiers rottoli 1.190; Damascus rottoli 3.96; Tunis rottoli 1.110; Tripoli rottoli 1.120; Cyprus rottoli 5.24; Candia rottoli 1.164; Aleppo rottoli 4.89; Aleppo oke 2.79; Constantinople oke 2.81; Smyrna oke 2.74; Mocha maund 3.00; Morea pound 1.101; Bengal seer 1.867; Batavia catty 1.302; China catty 1.326; Japan catty 1.300; Sumatra catty 2.81. Streeter gives 1 carat (diamond) in Lisbon 205.750, in Borneo 105.000, and in Madras 207.353 3 milligrams

WEIGHTS or MASSES and LENGTHS; WEIGHTS of WIRES, RAILS, BARS; FORCES and LENGTHS; FILM or SURFACE TENSION; CAPILLARITY.
(Mass $\div$ length; force $\div$ length.)

In this group of units the masses, forces, and the weights considered as both masses and forces have all been combined to avoid repetition of their relations to each other. When the units involve masses or weights considered as masses, as in pounds per foot, they are used to measure such quantities as the weights of rails, bars, wires, etc.; while when the units involve forces or weights considered as forces, they are used to measure such quantities as surface tension, capillarity, etc. The dimensions of the units in the two cases are different. Weights considered as forces involve the value of gravity, but masses and forces do not.

Aprx. means within 2%.

	Logarithm
1 dyne per centimeter [dyne/cm]:	
= 0.039 973 9 grain per inch. Aprx. $4 \div 100$	2.601 7764
= 0.001 019 79 gram per centimeter. Aprx. $1 \div 1\ 000$	3.008 5096
= 0.000 183 719 poundal per inch. Aprx. $1\frac{1}{6} \div 10\ 000$	4.264 1530
1 pound (av.) per mile [lb/ml]:	
= 0.281 849 kilogram per kilometer. Aprx. $\frac{2}{7}$	1.450 0161
= 0.110 480 grain per inch. Aprx. $\frac{1}{6}$	1.043 2829
= 0.002 818 49 gram per centimeter. Aprx. $\frac{2}{7} \div 100$	3.450 0161
= 0.000 568 182 pound per yard. Aprx. $\frac{4}{7} \div 1\ 000$	4.754 4873
= 0.000 281 849 kilogram per meter. Aprx. $\frac{2}{7} \div 1\ 000$	4.450 0161
= 0.000 189 394 pound per foot. Aprx. $19 \div 100\ 000$	4.277 3661
1 kilogram per kilometer [kg/km] or gram per meter [g/m] or milligram per millimeter [mg/mm]:	
= 9.805 97 dynes per centimeter. Aprx. 10	0.991 4904
= 3.548 00 pounds per mile. Aprx. $\frac{7}{2}$	0.549 9839
= 0.391 983 grain per inch. Aprx. $\frac{4}{10}$	1.593 2668
= 0.01 gram per centimeter.....	2.000 0000
= 0.002 015 91 pound per yard. Aprx. $2 \div 1\ 000$	3.304 4713
= 0.001 801 54 poundal per inch. Aprx. $\frac{9}{5} \div 1\ 000$	3.255 6434
= 0.001 kilogram per meter.....	3.000 0000
= 0.000 671 970 pound per foot. Aprx. $\frac{2}{3} \div 1\ 000$	4.827 3500
1 grain per inch [gr/in]:	
= 25.016 3 dynes per centimeter. Aprx. $\frac{1}{4} \times 100$	1.398 2236
= 9.051 4 pounds per mile. Aprx. 9	0.956 7171
= 2.551 14 kilograms per kilometer. Aprx. $\frac{1}{4} \times 10$	0.406 7332
= 0.025 511 4 gram per centimeter. Aprx. $\frac{1}{4} \div 10$	2.406 7332
= 0.005 142 86 pound per yard. Aprx. $51 \div 10\ 000$	3.711 2045
= 0.004 595 96 poundal per inch. Aprx. $\frac{9}{13} \div 100$	3.662 3766
= 0.002 551 14 kilogram per meter. Aprx. $\frac{1}{4} \div 100$	3.406 7332
= 0.001 714 3 pound per foot. Aprx. $17 \div 10\ 000$	3.234 0832
= 0.000 142 857 pound per inch. Aprx. $\frac{1}{7} \div 1\ 000$	4.154 9020
1 gram per centimeter [g/cm]:	
= 980.597 dynes per centimeter. Aprx. $1\ 000$	2.991 4904
= 354.800 pounds per mile. Aprx. $\frac{7}{2} \times 100$	2.549 9839
= 100. kg per km or g per m or mg per mm.....	2.000 0000
= 39.198 3 grains per inch. Aprx. 39	1.593 2668
= 0.201 591 pound per yard. Aprx. $\frac{1}{5}$	1.304 4713
= 0.180 154 poundal per inch. Aprx. $\frac{9}{5} \div 10$	1.255 6434
= 0.1 kilogram per meter.....	1.000 0000
= 0.067 197 0 pound per foot. Aprx. $\frac{2}{3} \div 10$	2.827 3500
= 0.005 599 75 pound per inch. Aprx. $\frac{9}{5} \div 100$	3.748 1688
1 pound per yard [lb/yd]:	
= 1 760. pounds per mile. Aprx. $\frac{7}{4} \times 1\ 000$	3.245 5127
= 496.054 kilograms per kilometer. Aprx. $\frac{1}{2} \times 1\ 000$	2.695 5287
= 194.444 grains per inch. Aprx. $\frac{1}{51} \times 10\ 000$	2.288 7955
= 4.960 54 grams per centimeter. Aprx. 5	0.695 5287
= 0.496 054 kilogram per meter. Aprx. $\frac{1}{2}$	1.695 5287
= 0.333 333 pound per foot or $\frac{1}{3}$	1.522 8787
= 0.027 777 8 pound per inch. Aprx. $1\frac{1}{4} \div 100$	2.443 6975

1 poundal per inch	= 5 443.11 dynes per cm. Aprx. $\frac{1}{2} \times 1\ 000$	3.735 8470
"	= 217.582 grains per inch. Aprx. $\frac{1}{2} \times 100$	2.337 6234
"	= 5.550 81 grams per centimeter. Aprx. $\frac{1}{2}$	0.744 3566
1 kilogram per meter [kg/m]:		
=	3 548.00 pounds per mile. Aprx. $\frac{7}{2} \times 1\ 000$	3.549 9830
=	1 000. kilograms per kilometer.....	3.000 0000
=	391.983 grains per inch. Aprx. 400.....	2.593 2663
=	10. grams per centimeter.....	1.000 0000
=	2.015 91 pounds per yard. Aprx. 2.....	0.304 4713
=	0.671 970 pound per foot. Aprx. $\frac{2}{3}$	1.827 3500
=	0.055 997 5 pound per inch. Aprx. $\frac{1}{2} + 100$	2.748 1688
1 pound per foot [lb/ft]:		
=	5 280. pounds per mile. Aprx. $\frac{1}{10} \times 100\ 000$	3.722 6340
=	1 488.16 kilograms per kilometer. Aprx. $\frac{3}{2} \times 1\ 000$...	3.172 6500
=	583.333 grains per inch. Aprx. $\frac{1}{17} \times 10\ 000$	2.765 9168
=	14.881 6 grams per centimeter. Aprx. $\frac{3}{2} \times 10$	1.172 6500
=	3. pounds per yard.....	0.477 1213
=	1.488 16 kilograms per meter. Aprx. $\frac{3}{2}$	0.172 6500
=	0.083 333 3 pound per inch. Aprx. $\frac{5}{6} + 10$	2.920 8188
1 pound per inch [lb/in]=	7 000. grains per inch.....	3.845 0980
"	= 178.579 gram/cm. Aprx. $\frac{9}{10} \times 100$	2.251 8312
"	= 36. pounds per yard.....	1.556 3025
"	= 17.857 9 kg per metr. Aprx. $\frac{9}{10} \times 10$	1.251 8312
"	= 12. pounds per foot.....	1.079 1812
Ton per mile.	A term popularly though incorrectly used for "ton-mile," which see under units of Energy. It is never used in the sense that a mile of something weighs a ton, except possibly in referring to submarine cables, rails, etc.	

PRESSURES; PRESSURES of WATER, MERCURY, and ATMOSPHERE; STRESS or FORCE per UNIT AREA. WEIGHTS or FORCES and SURFACES; WEIGHTS of SHEETS, DEPOSITS, COATINGS, etc. (Force $\div$ surface; mass $\div$ surface.)

The pressures of water columns have all (including those involving only non-metric units) been calculated on the uniform basis that a cubic decimeter of water weighs one kilogram (see notes under Volumes and Weights).

The pressures of mercury columns have all been calculated on the basis that the specific gravity of mercury is 13.595 93, which is the value accepted by the International Bureau of Weights and Measures, and by the (U. S.) National Bureau of Standards. This is the value used in the legal definition of the liter in reference to the atmospheric pressure.

The pressure of the atmosphere here used as a standard is that equal to 760 millimeters of mercury of the specific gravity given above.

To convert barometric pressures from millimeters to inches or the reverse, use the reduction factors for one millimeter of mercury in inches of mercury or the reverse.

In this group of units, the forces, masses, and the weights, considered as both forces and masses, have all been combined to avoid repetition of their relations to each other. When the units involve forces, or weights considered as forces, they are used to measure pressures or stresses per unit area; while when the units involve masses, or weights considered as masses, they are used to measure the weights of sheets, as those of metals. For instance, pounds per square foot may represent a pressure or the weight of a sheet of metal; in the former case the pound is a force and in the latter a mass. The dimensions of the units in the two cases are different. Weights considered as forces involve the value of gravity, but masses and true units of force do not.

Aprx. means within 2%. Hg means mercury.

	Logarithm
1 dyne per square centimeter [dyne/cm²]:	
= 1. barie†.....	0.000 0000
= 0.067 197 0 poundal per square foot. Aprx. $\frac{2}{3} \div 10$...	2.827 3501
= 0.010 197 9 kilogram per square meter. Aprx. $\frac{1}{100}$	2.008 5096
= 0.01 megadyne per square meter.....	2.000 0000
= 0.002 088 70 pound per square foot. Aprx. $21 \div 10\ 000$.	3.319 8754
= 0.000 750 068 millimeter of mercury. Aprx. $\frac{1}{2} \div 1\ 000$...	4.875 1006
= 0.000 466 646 poundal per square inch. Aprx. $1\frac{1}{2} \div 10\ 000$	4.668 9876
1 barie † (Fr. barye) = 1. dyne per square centimeter.	
1 gram per square decimeter [g/dm²]:	
= 0.1 kilogram per sq. m, which see for other values.	1.000 0000
= 0.020 481 7 pound per square foot. Aprx. $205 \div 10\ 000$...	2.311 3659
1 poundal per square foot:	
= 14.881 6 dynes per square centimeter. Aprx. $\frac{3}{2} \times 10$...	1.172 6499
= 0.151 761 kilogram per square meter. Aprx. $\frac{3}{2} \div 10$...	1.181 1595
= 0.031 083 2 pound per square foot. Aprx. $\frac{1}{32}$	2.492 5253
= 0.011 162 2 millimeter of mercury. Aprx. $\frac{1}{9} \div 10$	2.047 7504
1 kilogram per square meter [kg/m²]:	
= 98.059 66 dynes per square centimeter. Aprx. 100.	1.991 4904
= 10. grams per square decimeter.....	1.000 0000
= 6.589 32 poundals per square foot. Aprx. $\frac{2}{3} \times 10$.	0.818 8405
= 0.204 817 pound per sq. foot. Aprx. $205 \div 1\ 000$...	1.311 3659
= 0.1 gram per square centimeter.....	1.000 0000
= 0.073 551 4 millimeter of mercury. Aprx. $\frac{3}{4} \div 10$...	2.866 5910
= 0.045 759 2 poundal per square inch. Aprx. $\frac{1}{2} \div 100$.	2.660 4780
= 0.003 280 83 foot of water. Aprx. $\frac{1}{3} \div 100$	3.515 9842
= 0.002 895 72 inch of mercury. Aprx. $\frac{2}{7} \div 100$	3.461 7564
= 0.001 422 34 pound per square inch. Aprx. $\frac{1}{7} \div 100$...	3.153 0034
= 0.001 meter of water.....	3.000 0000
= 0.000 102 408 ton (short)/sq. ft. Aprx. $102 \div 1\ 000\ 000$	4.010 3359
= 0.000 1 kilogram per square centimeter.....	4.000 0000
= 0.000 096 778 2 atmosphere. Aprx. $29\frac{2}{3} \div 100\ 000$	5.985 7774
= 0.000 091 436 1 ton (long) per sq. ft. Aprx. $\frac{1}{11} \div 1\ 000$...	5.961 1179
1 megadyne per square meter:	
= 100. dynes per sq. cm, which see for other values.....	2.000 0000
1 pound per square foot [lb/ft²]:	
= 478.767 dynes per square centimeter. Aprx. 480...	2.680 1246
= 48.824 1 grams per square decimeter. Aprx. 49....	1.688 6341
= 32.171 7 poundals per square foot. Aprx. $\frac{1}{31} \times 1\ 000$.	1.507 4746
= 4.882 41 kilograms per square meter. Aprx. $\frac{4}{11}$	0.688 6341
= 0.359 108 millimeter of mercury. Aprx. $\frac{4}{11}$	1.555 2251
= 0.016 018 4 foot of water. Aprx. $\frac{8}{5} \div 100$	2.204 6183
= 0.014 138 1 inch of mercury. Aprx. $\frac{7}{5} \div 100$	2.150 3905
= 0.006 944 44 pound per square inch. Aprx. $7 \div 1\ 000$...	3.841 6375
= 0.004 882 41 meter of water. Aprx. $49 \div 10\ 000$	3.688 6341
= 0.000 5 ton (short) per square foot or $\frac{1}{2} \div 1\ 000$...	4.698 9700
= 0.000 488 241 kilogram per sq. cm. Aprx. $49 \div 100\ 000$...	4.688 6341
= 0.000 472 511 atmosphere. Aprx. $47 \div 100\ 000$	4.674 4115
= 0.000 446 429 ton (long) per sq. foot. Aprx. $\frac{4}{9} \div 1\ 000$...	4.649 7520
1 gram per square centimeter [g/cm²]:	
= 10. kilograms per sq. m, which see for other values.....	1.000 0000

† Recommended by a Committee of the International Physical Congress of 1900, in Paris, for the absolute unit of pressure, that is, for one dyne per sq. centimeter. It seems it was not officially adopted by that Congress. The recommendation includes that the megabarie (or megabarye) is represented with sufficient accuracy for practical purposes by the pressure of 75 cm of mercury at 0° C.; this latter is nearly what is usually accepted as the pressure of one atmosphere, namely 76 cm of mercury. It was originally proposed to the Congress to adopt this name barie for the atmospheric pressure, making it equal to a megadyne per sq. centimeter, but this was changed by the Committee of that Congress; it is, however, sometimes used in this sense.

1 millimeter of mercury column [mm Hg]:

=	1 333.21	dynes per sq. cm.	Aprx. $\frac{4}{3} \times 1\ 000$	3.124 8994
=	89.587 9	poundals per square foot.	Aprx. 90.....	1.952 2495
=	13.595 93†	kilograms per sq. meter.	Aprx. $\frac{4}{3} \times 10$	1.133 4090
=	2.784 68	pounds per square foot.	Aprx. $\frac{11}{4}$	0.444 7749
=	0.622 138	poundal per square inch.	Aprx. $\frac{5}{8}$	1.793 8870
=	0.044 606 0	foot of water.	Aprx. $\frac{1}{2} \div 10$	2.649 3932
=	0.039 370 0	inch of mercury.	Aprx. $4 \div 100$	2.595 1654
=	0.019 338 0	pound per square inch.	Aprx. $19 \div 1\ 000$..	2.286 4124
=	0.013 595 93	meter of water.	Aprx. $\frac{4}{3} \div 100$	2.133 4090
=	0.001 392 34	ton (short) per square foot.	Aprx. $\frac{7}{8} \div 1\ 000$..	3.143 7449
=	0.001 359 59	kilogram per sq. cm.	Aprx. $\frac{4}{3} \div 1\ 000$	3.133 4090
=	0.001 315 79	atmosphere.	Aprx. $\frac{4}{3} \div 1\ 000$	3.119 1864
=	0.001 243 16	ton (long) per sq. foot.	Aprx. $\frac{1}{8} \div 100$	3.094 5269

1 poundal per square inch:

=	2 142.95	dynes per sq. cm.	Aprx. $\frac{3}{4} \times 10\ 000$	3.331 0124
=	21.853 6	kilograms per square meter.	Aprx. $\frac{11}{5} \times 10$..	1.339 5220
=	1.607 36	millimeters of mercury.	Aprx. $\frac{8}{5}$	0.206 1130
=	0.031 083 2	pound per square inch.	Aprx. $\frac{1}{32}$	2.492 5253

1 foot of water column =

	=	62.428 3	lbs/sq. ft.	Aprx. $\frac{5}{8} \times 100$	1.795 3817
"	=	22.418 5	mm Hg.	Aprx. $\frac{9}{4} \times 10 \dots$	1.350 6068
"	=	0.882 617	inch Hg.	Ap. subtr. $\frac{1}{2}$.	1.945 7722
"	=	0.433 530	lb per sq. inch.	Aprx. $\frac{3}{4}$.	1.637 0192
"	=	0.304 801	meter of water.	Aprx. $\frac{3}{40}$	1.484 0158
"	=	0.031 214 2	sh. ton/ft ² .	Aprx. $\frac{1}{32} \dots$	2.494 3517
"	=	0.030 480 1	kg/cm ² .	Aprx. $3 \div 100 \dots$	2.484 0158
"	=	0.029 498 0	atm.	Aprx. $3 \div 100 \dots$	2.469 7932
"	=	0.027 869 8	l. ton/ft ² .	Ap. $\frac{1}{4} \div 100 \dots$	2.445 1337

1 inch of mercury column [in Hg]:

=	345.337	kilograms per sq. meter.	Aprx. $\frac{7}{2} \times 100$	2.538 2436
=	70.731 0	pounds per square foot.	Aprx. 70.....	1.849 6095
=	25.400 05	millimeters of mercury.	Aprx. $\frac{1}{4} \times 100$	1.404 8346
=	1.132 99	feet of water.	Aprx. $\frac{10}{9}$	0.054 2278
=	0.491 187	pound per square inch.	Aprx. $\frac{1}{2}$	1.691 2470
=	0.345 337	meter of water.	Aprx. $\frac{7}{20}$	1.538 2436
=	0.035 365 5	ton (short) per sq. foot.	Aprx. $\frac{7}{2} \div 100$	2.548 5795
=	0.034 533 7	kilogram per sq. centimeter.	Aprx. $\frac{7}{2} \div 100$..	2.538 2436
=	0.033 421 1	atmosphere.	Aprx. $\frac{1}{30}$	2.524 0210
=	0.031 576 3	ton (long) per sq. foot.	Aprx. $\frac{1}{32}$	2.499 3615

1 pound per square inch [lb/in²]:

=	703.067	kilograms per sq. meter.	Aprx. 700.....	2.846 9966
=	144.	pounds per square foot.	Aprx. $\frac{1}{4} \times 1\ 000$	2.158 3625
=	51.711 6	millimeters of mercury.	Aprx. $\frac{31}{6} \times 10$	1.713 5876
=	32.171 7	poundals per sq. inch.	Aprx. $\frac{1}{31} \times 1\ 000$	1.507 4746
=	2.306 65	feet of water.	Aprx. $\frac{7}{8}$	0.362 9808
=	2.035 88	inches of mercury.	Aprx. 2.....	0.308 7530
=	0.703 067	meter of water.	Aprx. $\frac{7}{40}$	1.846 9966
=	0.072	ton (short) per square foot.	Aprx. $\frac{1}{14}$	2.857 3325
=	0.070 306 7	kilogram per sq. centimeter.	Aprx. $7 \div 100$..	2.846 9966
=	0.068 041 5	atmosphere.	Aprx. $\frac{2}{30}$	2.832 7740
=	0.064 285 7	ton (long) per sq. foot.	Aprx. $\frac{7}{11} \div 10$	2.808 1145

1 meter of water column or**1 metric ton per square meter [t/m²]:**

=	1 000.	kilograms per square meter.....	3.000 0000
=	204.817	pounds per square foot. Aprx. 205.....	2.311 3659
=	73.551 4	millimeters of mercury. Aprx. $\frac{3}{4} \times 100$	1.866 5910
=	3.280 83	feet of water. Aprx. $\frac{1}{3} \times 10$	0.515 9842
=	2.895 72	inches of mercury. Aprx. $\frac{20}{7}$	0.461 7564
=	1.422 34	pounds per sq. inch. Aprx. $\frac{1}{4} \times 10$	0.153 0034
=	0.102 408	ton (short) per sq. foot. Aprx. $\frac{4}{14} \div 100$	1.010 3359
=	0.1	kilogram per square centimeter.....	1.000 0000
=	0.096 778 2	atmosphere. Aprx. $97 \div 1\ 000$	2.985 7774
=	0.091 436 1	ton (long) per square foot. Aprx. $\frac{1}{11}$	2.961 1179

† This is the specific gravity of mercury used throughout in these tables.

1 ton (short) per square foot [tn/ft²]:

=	9 764.82 kilograms per square meter.	Aprx. 9 800...	3.989 8641
=	2 000. pounds per square foot.	.....	3.301 0300
=	718.216 millimeters of mercury.	Aprx. $\frac{5}{8} \times 1\,000$..	2.858 2551
=	32.036 7 feet of water.	Aprx. 32	1.505 8483
=	28.276 2 inches of mercury.	Aprx. $\frac{3}{8} \times 100$	1.451 4205
=	13.888 9 pounds per square inch.	Aprx. $\frac{7}{8} \times 10$	1.142 6675
=	9.764 82 meters of water.	Aprx. $98 \div 10$	0.989 8641
=	0.976 482 kilogram per sq. cm.	Aprx. subtract $\frac{1}{30}$...	1.989 8641
=	0.945 021 atmosphere.	Aprx. subtract $\frac{1}{20}$	1.975 4415
=	0.892 857 ton (long) per sq. ft.	Aprx. subtract $\frac{1}{10}$	1.950 7820
=	0.006 944 44 ton (short) per sq. inch.	Aprx. $7 \div 1\,000$...	3.841 6375
=	0.006 200 40 ton (long) per sq. inch.	Aprx. $\frac{5}{8} \div 100$	3.792 4195

1 kilogram per square centimeter [kg/cm²]:

=	10 000. kilograms per square meter.		4.000 0000
=	2 048.17 pounds per square foot.	Aprx. 2 050	3.311 3659
=	735.514 millimeters of mercury.	Aprx. $\frac{3}{4} \times 1\,000$	2.866 5910
=	32.808 3 feet of water.	Aprx. $\frac{1}{3} \times 100$	1.515 9842
=	28.957 2 inches of mercury.	Aprx. $\frac{3}{8} \times 100$	1.461 7564
=	14.223 4 pounds per sq. inch.	Aprx. $\frac{1}{4} \times 100$	1.153 0034
=	10. meters of water.	.....	1.000 0000
=	1.024 08 tons (short) per sq. foot.	Aprx. add $\frac{1}{40}$	0.010 3359
=	0.967 782 atmosphere.	Aprx. subtract $\frac{1}{30}$	1.985 7774
=	0.914 361 ton (long) per square foot.	Aprx. $10\frac{1}{11}$	1.961 1179
=	0.001 metric ton per square centimeter		3.000 0000

1 barie † = 75 centimeters of Hg (aprx.). Accurately 75.0068.

" = 1 megadyne per square centimeter.

1 megabarie ‡ = 1 megadyne per square centimeter. 0.000 0000**1 megadyne per sq. cm. = 750.068 mm. of Hg.** Aprx. $\frac{3}{4} \times 1\,000$ 2.875 1006

" = 0.986 931 atmosphere (stand.) Ap. 1 1.994 2870

1 atmosphere [atm] (standard):

=	10 332.9 kilograms per square meter.	Aprx. 10 300	4.014 2226
=	2 116.35 pounds per square foot.	Aprx. 2 100	3.325 5885
=	760. millimeters of mercury.	Aprx. $\frac{3}{4} \times 1\,000$	2.880 8136
=	33.900 6 feet of water.	Aprx. $\frac{1}{3} \times 100$	1.530 2068
=	29.921 2 inches of mercury.	Aprx. 30	1.475 9780
=	14.696 9 pounds per square inch.	Aprx. $4\frac{2}{3}$	1.167 2260
=	10.332 9 meters of water.	Aprx. $10\frac{1}{3}$	1.014 2226
=	1.058 18 tons (short) per sq. foot.	Aprx. add $\frac{1}{20}$	0.024 5585
=	1.033 29 kilograms per sq. cm.	Aprx. add $\frac{1}{30}$	0.014 2226
=	1.013 24 megadynes per sq. centimeter.	Aprx. 1	0.005 7130
=	1.013 24 megabaries. ‡	Aprx. 1	0.005 7130
=	0.944 801 ton (long) per sq. foot.	Aprx. subtract $\frac{1}{20}$...	1.975 3405

1 ton (long) per square foot [tn/ft²]:

=	10 936.6 kilograms per sq. meter.	Aprx. 11 000	4.038 8821
=	2 240. pounds per square foot.	Aprx. $\frac{9}{8} \times 1\,000$..	3.350 2480
=	804.402 millimeters of mercury.	Aprx. 800	2.905 4731
=	35.881 1 feet of water.	Aprx. $4\frac{1}{11} \times 100$	1.554 8663
=	31.669 3 inches of mercury.	Aprx. 32	1.500 6385
=	15.555 6 pounds per square inch.	Aprx. $31\frac{1}{2}$	1.191 8855
=	10.936 6 meters of water.	Aprx. 11	1.038 8821
=	1.12 tons (short) per sq. foot.	Aprx. add $\frac{1}{8}$	0.049 2180
=	1.093 66 kilograms per square cm.	Aprx. add $\frac{1}{10}$...	0.038 8821
=	1.058 42 atmospheres.	Aprx. add $\frac{1}{20}$	0.024 6595
=	0.007 777 78 ton (short) per sq. inch.	Aprx. $\frac{7}{8} \div 100$	3.890 8555
=	0.006 944 44 ton (long) per sq. inch.	Aprx. $7 \div 1\,000$...	3.841 6375

1 kilogram per square millimeter [kg/mm²]:

= 100. kilograms per sq. cm, which see for other values. ... 2.000 0000

1 ton (short) per square inch [tn/in²]:

=	144. tons (short) per sq. foot.	Aprx. $\frac{1}{4} \times 1\,000$	2.158 3625
=	140.613 kilograms per sq. cm.	Aprx. $\frac{7}{8} \times 100$	2.148 0266
=	136.083 atmospheres.	Aprx. $\frac{4}{8} \times 100$	2.133 8040
=	0.892 857 ton (long) per sq. inch.	Aprx. subtr. $\frac{1}{10}$	1.950 7820
=	0.140 613 metric ton per sq. centimeter.	Aprx. $\frac{1}{7}$	1.148 0266

† Not authoritative; see foot-note on page 64.

‡ Authoritative; see foot-note on page 64.

1 ton (long) per square inch [tn/in²]:

= 157.487 kilograms per sq. centimeter.	Aprx. $1\frac{1}{4} \times 100$	2.197 2446
= 152.413 atmospheres.	Aprx. $\frac{3}{2} \times 100$	2.183 0220
= 144. tons (long) per sq. foot.	Aprx. $\frac{1}{4} \times 1\ 000$	2.158 3625
= 1.12 tons (short) per square inch.	Aprx. add $\frac{1}{8}$	0.049 2180
= 0.157 487 metric ton per sq. cm.	Aprx. $1\frac{1}{4} \div 10$	1.197 2446

1 metric ton per square centimeter [t/cm²]:

= 1 000. kilograms per sq. cm, which see for other values..		3.000 0000
= 967.782 atmospheres.	Aprx. 970	2.985 7774
= 7.111 70 tons (short) per sq. inch.	Aprx. $\frac{5}{4} \times 10$	0.851 9734
= 6.349 73 tons (long) per sq. inch.	Aprx. $\frac{5}{8} \times 10$	0.802 7554

Conversion Tables for Pressures.

Pounds per sq. inch =	kilogram per sq. cm.	lbs. per sq. in.	lbs. per sq. in.	atmos- pheres.	kg. per sq. cm.	atmos- pheres.
Kilograms per sq. cm =	.....	.....	.....	.....	.....	.....
Atmosph's =	.....	.....	.....	.....	.....	.....
1	0.070 307	14.223	14.697	0.068 042	1.033 3	0.967 78
2	0.140 61	28.447	29.394	0.136 08	2.066 6	1.935 6
3	0.210 92	42.670	44.091	0.204 12	3.099 9	2.903 3
4	0.281 23	56.894	58.788	0.272 17	4.133 2	3.871 1
5	0.351 53	71.117	73.485	0.340 21	5.166 5	4.838 9
6	0.421 84	85.340	88.181	0.408 25	6.199 7	5.806 7
7	0.492 15	99.564	102.88	0.476 29	7.233 0	6.774 5
8	0.562 45	113.79	117.58	0.544 33	8.266 3	7.742 3
9	0.632 76	128.01	132.27	0.612 37	9.299 6	8.710 0
10	0.703 07	142.23	146.97	0.680 42	10.333	9.677 8

**WEIGHTS or MASSES and VOLUMES; DENSITIES;
WEIGHTS of MATERIALS; MASSES per unit of
VOLUME. (Weight $\div$ volume.)**

Only the more usual units are given here, as the table would otherwise have become very long and cumbersome. The relations between such compound units as these are the same as those between their individual units whenever one of the latter is the same in both; for instance, the relation between pounds per *cubic yard* and kilograms per *cubic yard* is the same as between pounds and kilograms, and as these are given in the tables of weights they are not repeated here. In such a reduction multiply the pounds per cubic yard by the value of 1 pound in kilograms. Similarly, the relation between *pounds* per cubic yard and *pounds* per cubic meter is the same as that between a cubic meter and a cubic yard, but in this case care must be taken in the reduction on account of the word "per," not to *multiply* the former by the value of one cubic yard in cubic meters, but to *divide* instead, as a cubic yard is *smaller* than a cubic meter, hence the weight per cubic meter is *larger*. To avoid such a long division use instead the reciprocal relation, namely, the value of one cubic meter in cubic yards and then multiply. The general rule for all compound units is that if the individual unit to be changed is preceded by the word "per," then *divide* by the value of the old unit in terms of the new one (or multiply by its reciprocal); in all other cases multiply, even when the unit follows a hyphen, as, for instance, in the case of pounds in foot-pounds.

In this group of units the weights are always masses and never forces; no unit exists having the dimensions of force divided by volume. The value of gravity is therefore not involved in these values.

Weights of Materials. In the metric system the number representing the density or specific gravity also represents the actual weight in grams of a cubic centimeter of the material. Hence the actual weight of any other

unit of volume of that material in terms of any other unit of weight is determined by merely multiplying the specific gravity or density (when based on water, as is usual for all materials except gases) by the value of 1 gram per cubic centimeter in terms of those units as given in the table below. Thus the weight of any material in pounds per cubic foot is 62.43 multiplied by its specific gravity, this figure 62.43 being the value of 1 gram per cubic centimeter in terms of pounds per cubic foot. Similarly, the specific gravity or density is easily calculated by means of the figures in this table, when the weight of a unit of volume is given in terms of any of the usual non-metric units. Thus if the weight of any material is, say, 100 pounds per cubic foot, its specific gravity is 0.016 02 (which is the value of 1 pound per cubic foot in terms of grams per cubic centimeter in the table) multiplied by 100, that is 1.602.

Aprx. means within 2%.

	Logarithm
1 pound per cubic yard [lb/yd³]:	
= 0.593 273 kilogram per cubic meter. Aprx. $\frac{9}{10}$	1.773 2545
= 0.037 037 0 or $\frac{1}{27}$ pound per cb. ft. Aprx. $\frac{3}{8} \div 10$	2.568 6362
= 0.000 593 273 gram per cb. cm or kg per lit. Ap. .0006...	4.773 2545
= 0.000 593 273 ton (met.) per cb. meter. Aprx. $6 \div 10$ 000.	4.773 2545
= 0.000 5 ton (short) per cubic yard or $\frac{1}{2} \div 1$ 000. ...	4.698 9700
= 0.000 446 429 ton (long) per cubic yard. Aprx. $\frac{4}{5} \div 1$ 000.	4.649 7520
1 kilogram per cubic meter [kg/m³]:	
= 1.685 56 pounds per cubic yard. Aprx. $\frac{1}{10}$	0.226 7455
= 0.062 428 3 pound per cubic foot. Aprx. $\frac{5}{8} \div 10$	2.795 3817
= 0.001 gram per cb. cm or kilogram per liter.....	3.000 0000
= 0.001 ton (met.) per cubic meter.....	3.000 0000
= 0.000 842 782 ton (short) per cb. yd. Aprx. $\frac{5}{6} \div 1$ 000...	4.925 7155
= 0.000 752 484 ton (long) per cb. yd. Aprx. $\frac{3}{4} \div 1$ 000...	4.876 4975
1 grain per cubic inch [gr/in³]:	
= 0.246 857 pound per cubic foot. Aprx. $\frac{1}{4}$	1.392 4457
= 0.003 954 25 gram per cb. cm or kg per lit. Aprx. $\frac{4}{1}$ 000...	3.597 0640
1 pound per bushel [lb/bu] (U. S.):	
= 12.871 8 kilograms per cubic meter. Aprx. $\frac{9}{7} \times 10$	1.109 6387
= 1.287 18 kilograms per hectoliter. Aprx. $\frac{9}{7}$	0.109 6387
= 1.032 02 pounds per bushel (Brit.). Aprx. add $\frac{1}{30}$	0.013 6888
= 0.803 564 pound per cubic foot. Aprx. $\frac{4}{5}$	1.905 0204
1 pound per bushel [lb/bu] (Brit.):	
= 12.472 4 kilograms per cubic meter. Aprx. $\frac{1}{8} \times 100$	1.095 9499
= 1.247 24 kilograms per hectoliter. Aprx. $\frac{1}{8}$	0.095 9499
= 0.968 972 pound per bushel (U. S.). Aprx. subtr. $\frac{1}{30}$	1.986 3112
= 0.778 630 pound per cubic foot. Aprx. $\frac{7}{8}$	1.891 3316
1 kilogram per hectoliter [kg/hl]:	
= 10. kilograms per cubic meter, which see for other values.	1.000 0000
1 pound per cubic foot [lb/ft³]:	
= 27. pounds per cubic yard. Aprx. $\frac{8}{3} \times 10$	1.431 3638
= 16.018 4 kilograms per cubic meter. Aprx. $\frac{8}{5} \times 10$...	1.204 6183
= 4.050 93 grains per cubic inch. Aprx. 4.....	0.607 5543
= 1.601 84 kilograms per hectoliter. Aprx. $\frac{8}{5}$	0.204 6183
= 1.284 31 pounds per bushel (Brit.). Aprx. $\frac{9}{7}$	0.108 6684
= 1.244 46 pounds per bushel (U. S.). Aprx. $1\frac{1}{4}$	0.094 9796
= 0.160 538 pound per gallon (Brit.). Aprx. $\frac{8}{5} \div 10$	1.205 5784
= 0.133 681 pound per gallon (liquid; U.S.). Aprx. $\frac{4}{3} \div 10$	1.126 0683
= 0.016 018 4 gram per cb. cm or kg per lit. Aprx. $\frac{8}{5} \div 100$..	2.204 6183
= 0.016 018 4 ton (met.) per cubic meter. Aprx. $\frac{8}{5} \div 100$..	2.204 6183
= 0.013 5 ton (short) per cubic yard. Aprx. $\frac{4}{3} \div 100$..	2.130 3338
= 0.012 053 6 ton (long) per cubic yard. Aprx. $\frac{8}{5} \div 100$..	2.081 1158
1 pound per gallon [lb/gal] (liquid; U. S.):	
= 7.480 52 pounds per cubic foot. Aprx. $\frac{3}{4} \times 10$	0.873 9317
= 1.200 91 pounds per gallon (Brit.). Aprx. add $\frac{1}{5}$	0.079 5101
= 0.119 826 gram per cb. cm or kg per lit. Aprx. $12 \div 100$..	1.078 5500
1 pound per gallon [lb/gal] (Brit.):	
= 6.229 05 pounds per cubic foot. Aprx. $6\frac{1}{4}$	0.794 4216
= 0.832 702 4 pound per gallon (liquid; U. S.). Aprx. $\frac{8}{5}$...	1.920 4899
= 0.099 779 2 gram per cb. cm or kg per liter. Aprx. $\frac{1}{10}$	2.999 0399
1 pound per quart [lb/qt]= 4. pounds per gallon.....	0.602 0600

1 gram per cubic centimeter [g/cm³] or

1 kilogram per liter [kg/l] or

1 ton (met.) per cubic meter [t/m³]:

=	1 685.57	pounds per cubic yard.	Aprx. $\frac{1}{16} \times 10\ 000$...	3.226 7455
=	1 000.	kilograms per cubic meter	.....	3.000 0000
=	252.893	grains per cubic inch.	Aprx. $\frac{1}{4} \times 1\ 000$	2.402 9360
=	100.	kilograms per hectoliter	.....	2.000 0000
=	80.177 1	pounds per bushel (Brit.).	Aprx. 80.	1.904 0501
=	77.68 93	pounds per bushel (U. S.).	Aprx. $\frac{7}{10} \times 100$..	1.890 3613
=	62.428 3	pounds per cubic foot.	Aprx. $\frac{5}{8} \times 100$	1.795 3817
=	10.022 1	pounds per gallon (Brit.).	Aprx. 10.	1.000 9601
=	8.345 45	pounds per gal (liquid; U.S.).	Aprx. $\frac{1}{42} \times 100$	0.921 4500
=	0.842 783	ton (short) per cubic yard.	Aprx. subtr. $\frac{1}{16}$..	1.925 7155
=	0.752 484	ton (long) per cubic yard.	Aprx. $\frac{3}{4}$	1.876 4975
=	0.036 127 5	pound per cubic inch.	Aprx. $\frac{4}{11} \div 10$	2.557 8380
=	0.001	kilogram per cubic centimeter	.....	3.000 0000

1 ton (short) per cubic yard [tn/yd³]:

=	1 186.55	kilograms per cubic meter.	Aprx. $\frac{9}{10} \times 1\ 000$...	3.074 2845
=	118.655	kilograms per hectoliter.	Aprx. $\frac{9}{10} \times 100$	2.074 2845
=	95.133 7	pounds per bushel (Brit.).	Aprx. 95.	1.978 3346
=	92.181 9	pounds per bushel (U. S.).	Aprx. $\frac{1}{11} \times 1\ 000$...	1.964 6458
=	74.074 1	pounds per cubic foot.	Aprx. $\frac{3}{4} \times 100$	1.869 6662
=	1.186 55	tons (met.) per cb. m or kg per lit.	Ap. add $\frac{1}{10}$...	0.074 2845
=	0.892 857	ton (long) per cubic yard.	Aprx. $\frac{9}{10}$	1.950 7820

1 ton (long) per cubic yard [tn/yd³]:

=	1 328.93	kilograms per cubic meter.	Aprx. $\frac{4}{3} \times 1\ 000$	3.123 5025
=	132.893	kilograms per hectoliter.	Aprx. $\frac{4}{3} \times 100$	2.123 5025
=	106.550	pounds per bushel (Brit.).	Aprx. 107.	2.027 5526
=	103.244	pounds per bushel (U. S.).	Aprx. 103.	2.013 8638
=	82.963 0	pounds per cubic foot.	Aprx. $\frac{5}{6} \times 100$	1.918 8842
=	1.328 93	tons (met.) per cb. m or kg per lit.	Ap. add $\frac{1}{3}$..	0.123 5025
=	1.12	tons (short) per cubic yard.	Aprx. add $\frac{1}{10}$	0.049 2180

1 pound per cubic inch [lb/in³]:

=	27.679 7	grams per cb. centimeter.	Aprx. $\frac{1}{4} \times 10$	1.442 1620
=	0.027 679 7	kilogram per cubic centimeter.	Aprx. $\frac{1}{4} \div 100$	2.442 1620

1 kilogram per cubic centimeter [kg/cm³]:

=	1 000.	grams per cb. cm or tons (met.) per cb. m.....	3.000 0000
=	36.127 5	pounds per cubic inch. Aprx. 36.....	1.557 8380

WEIGHTS and VOLUMES of WATER.

Factors for calculating weights or volumes of materials from their specific gravity.

The following two groups of numbers give the weights (W) of all the different units of volume of water occurring in practice; also the volumes (V) of all the different units of weight of water occurring in practice; the latter are, of course, the reciprocals of the former and are given so as to avoid the long divisions by the former.

Besides their direct application to hydraulics and to the calibration of vessels and for measuring, or for the indirect determinations of irregular volumes by means of weights, they are also of use for determining the weights of materials, as the weight of a unit of volume of any material, whether solid or liquid, is its specific gravity or density multiplied by one of these factors, W; or the volume of a unit of weight of any material, whether solid or liquid, is one of these factors, V, divided by its specific gravity or density. They are applicable also to gases provided the value of the specific gravity or density which is used is based on water and not on air or hydrogen.

For the weights of columns of water, mercury, or the air, see under Pressures.

All these values, even those given entirely in English units, have been calculated from the uniform bases that one liter of water weighs one kilogram, and that a liter is equal to a cubic decimeter. (See notes on the liter in the introductory remarks on units of Volume and Weight.)

WEIGHTS of WATER, W.

Aprx. means within 2%.

		Logarithm
1 cubic centimeter =	15.423 4 grains. Aprx. $3\frac{1}{2}$ or $15\frac{1}{2}$..	1.188 4322
"	= 1. gram.....	0.000 0000
"	= 0.035 274 0 oz (av.). Aprx. $\frac{7}{2} \div 100$..	2.547 4541
"	= 0.002 204 62 lb (av.). Aprx. $\frac{2}{9} \div 100$...	3.343 3342
1 cubic inch =	252.893 grains. Aprx. $\frac{1}{4} \times 1000$	2.402 9360
"	= 16.387 2 grams. Aprx. $\frac{1}{8} \times 100$ or $3\frac{3}{4}$	1.214 5038
"	= 0.578 040 ounce (av.). Aprx. $\frac{4}{7}$	1.761 9579
"	= 0.036 127 5 pound (av.). Aprx. $\frac{4}{110}$	2.557 8380
1 pint (liquid; U. S.) =	1.043 18 pounds (av.). Aprx. add $\frac{1}{20}$..	0.018 3600
"	= 0.473 179 kilogram. Aprx. $\frac{1}{21} \times 10$	1.675 0258
1 pint (dry; U. S.) =	1.213 90 pounds (av.). Aprx. $\frac{9}{5}$	0.084 1813
"	= 0.550 614 kilogram. Aprx. $\frac{11}{2} \div 10$	1.740 8471
1 pint (Brit.) =	1.252 77 pounds (av.). Aprx. $\frac{5}{4}$	0.097 8701
"	= 0.568 245 39 kilogram. Aprx. $\frac{4}{7}$	1.754 5359
1 quart (liquid; U. S.) =	2.086 36 lb (av.). Aprx. $2\frac{1}{10}$ or $2\frac{1}{10}$..	0.319 3900
"	= 0.946 359 kilogram. Aprx. subtr. $\frac{1}{20}$...	1.976 0558
1 liter =	2.204 62 pounds (av.). Aprx. $2\frac{2}{10}$	0.343 3342
"	= 1. kilogram.....	0.000 0000
1 quart (dry; U. S.) =	2.427 79 pounds (av.). Aprx. $2\frac{4}{10}$ or $1\frac{2}{5}$..	0.385 2113
"	= 1.101 23 kilograms. Aprx. add $\frac{1}{10}$	0.041 8771
1 quart (Brit.) =	2.505 53 pounds (av.). Aprx. $1\frac{1}{4}$	0.398 9001
"	= 1.136 490 8 kilograms. Aprx. add $\frac{1}{7}$	0.055 5659
1 gallon (liquid; U. S.) =	8.345 45 pounds (av.). Aprx. $5\frac{5}{6}$	0.921 4500
"	= 3.785 43 kilograms. Aprx. $\frac{3}{8} \times 10$	0.578 1158
1 gallon (Brit.) =	10.022 1 pounds (av.). Aprx. 10.....	1.000 9601
"	= 4.545 963 1 kilograms. Aprx. $\frac{9}{2}$ or $4\frac{1}{2}$	0.657 6259
1 peck (U. S.) =	19.422 3 pounds (av.). Aprx. $\frac{1}{51} \times 1000$	1.288 3013
"	= 8.809 82 kilograms. Aprx. $\frac{7}{8} \times 10$	0.944 9671
1 peck (Brit.) =	20.044 3 pounds (av.). Aprx. 20.....	1.301 9901
"	= 9.091 926 2 kilograms. Aprx. 9 or $\frac{100}{11}$	0.958 6559
1 cubic foot =	62.428 3 pounds (av.). Aprx. $\frac{5}{8} \times 100$	1.795 3817
"	= 28.317 0 kilograms. Aprx. $\frac{3}{4} \times 100$	1.452 0475
"	= 0.031 214 2 ton (short). Aprx. $\frac{1}{32}$	2.494 3517
"	= 0.028 317 0 ton (met.). Aprx. $\frac{2}{70}$	2.452 0475
"	= 0.027 869 8 ton (long). Aprx. $\frac{1}{400}$	2.445 1337
1 bushel (U. S.) =	77.689 3 pounds (av.). Aprx. $\frac{7}{9} \times 100$	1.890 3613
"	= 35.239 28 kilograms. Aprx. 35.....	1.547 0271
1 bushel (Brit.) =	80.177 1 pounds (av.). Aprx. 80.....	1.904 0501
"	= 36.367 704 8 kilograms. Aprx. $\frac{4}{11} \times 100$	1.560 7159
1 hectoliter =	220.462 pounds (av.). Aprx. 220.....	2.343 3342
"	= 100. kilograms.....	2.000 0000
"	= 0.110 231 ton (short). Aprx. $\frac{1}{9}$	1.042 3042
"	= 0.1 ton (met.).....	1.000 0000
"	= 0.098 420 6 ton (long). Aprx. $\frac{1}{10}$	2.993 0862
1 cubic yard =	1 685.56 pounds (av.). Aprx. $\frac{1}{6} \times 10000$	3.226 7455
"	= 764.559 kilograms. Aprx. $\frac{3}{4} \times 1000$	2.883 4113
"	= 0.842 782 ton (short). Aprx. $\frac{9}{5}$	1.925 7155
"	= 0.764 559 ton (met.). Aprx. $\frac{3}{4}$	1.883 4113
"	= 0.752 484 ton (long). Aprx. $\frac{3}{4}$	1.876 4975
1 cubic meter =	2 204.62 pounds (av.). Aprx. 2 200.....	3.343 3342
"	= 1 000. kilograms.....	3.000 0000
"	= 1.102 31 tons (short). Aprx. add $\frac{1}{10}$	0.042 3042
"	= 1. ton (met.).....	0.000 0000
"	= 0.984 206 ton (long). Aprx. 1.....	1.993 0862

VOLUMES of WATER, V.

1 grain	=	0.064 798 9 cubic centimeter. Aprx. $1\frac{1}{2} \div 100$	2.811 5678
"	=	0.003 954 25 cubic inch. Aprx. $4 \div 1\ 000$	3.597 0640
1 gram	=	1. cubic centimeter.....	0.000 0000
"	=	0.061 023 4 cubic inch. Aprx. $6 \div 100$	2.785 4962
1 ounce (av.)	=	28.349 5 cubic centimeters. Aprx. $\frac{2}{7} \times 100$	1.452 5459
"	=	1.729 98 cubic inches. Aprx. $\frac{1}{4}$	0.238 0421
1 pound (av.)	=	453.592 cb. centimeters. Aprx. $\frac{9}{2} \times 100$..	2.656 6658
"	=	27.679 7 cubic inches. Aprx. $1\frac{1}{4} \times 10$	1.442 1620
"	=	0.958 606 pt (liquid; U.S.). Aprx. subtr. $\frac{1}{20}$..	1.981 6400
"	=	0.823 794 pint (dry; U.S.). Aprx. $\frac{5}{10}$	1.915 8187
"	=	0.798 233 pint (Brit.). Aprx. $\frac{4}{5}$ or $\frac{5}{10}$	1.902 1299
"	=	0.479 303 qt (liquid; U.S.). Aprx. $10 \div 21$..	1.680 6100
"	=	0.453 592 liter. Aprx. $10 \div 22$ or $\frac{5}{11}$	1.656 6658
"	=	0.411 897 quart (dry; U.S.). Aprx. $1\frac{1}{24}$..	1.614 7887
"	=	0.399 117 quart (Brit.). Aprx. $\frac{4}{10}$	1.601 0999
"	=	0.119 826 gal (liquid; U.S.). Aprx. $12 \div 100$..	1.078 5500
"	=	0.099 779 2 gallon (Brit.). Aprx. $\frac{1}{10}$	2.999 0399
"	=	0.051 487 1 peck (U.S.). Aprx. $51 \div 1\ 000$..	2.711 6987
"	=	0.049 889 6 peck (Brit.). Aprx. $\frac{1}{20}$	2.698 0099
"	=	0.016 018 4 cubic foot. Aprx. $\frac{8}{5} \div 100$	2.204 6183
"	=	0.012 871 8 bushel (U.S.). Aprx. $\frac{9}{7} \div 100$..	2.109 6387
"	=	0.012 472 4 bushel (Brit.). Aprx. $\frac{1}{80}$	2.095 9499
"	=	0.004 535 92 hectoliter. Aprx. $\frac{9}{2} \div 1\ 000$..	3.656 6658
"	=	0.000 593 273 cubic yard. Aprx. $6 \div 10\ 000$..	4.773 2545
"	=	0.000 453 592 cubic meter. Aprx. $\frac{9}{2} \div 10\ 000$..	4.656 6658
1 kilogram	=	1 000. cubic centimeters.....	3.000 0000
"	=	61.023 4 cubic inches. Aprx. 60.....	1.785 4962
"	=	2.113 36 pints (liquid; U.S.). Aprx. $2\frac{1}{10}$..	0.324 9742
"	=	1.816 15 pints (dry; U.S.). Aprx. $2\frac{9}{11}$	0.259 1529
"	=	1.759 80 pints (Brit.). Aprx. $\frac{1}{4}$	0.245 4641
"	=	1.056 68 quarts (liquid; U.S.). Aprx. add $\frac{1}{20}$..	0.023 9442
"	=	1. liter.....	0.000 0000
"	=	0.908 078 quart (dry; U.S.). Aprx. $\frac{9}{10}$	1.958 1229
"	=	0.879 902 quart (Brit.). Aprx. $\frac{7}{8}$	1.944 4341
"	=	0.264 170 gallon (liquid; U.S.). Aprx. $\frac{8}{30}$	1.421 8842
"	=	0.219 975 gallon (Brit.). Aprx. $22 \div 100$	1.342 3741
"	=	0.113 510 peck (U.S.). Aprx. $\frac{8}{7} \div 10$	1.055 0329
"	=	0.109 988 peck (Brit.). Aprx. $11 \div 100$	1.041 3441
"	=	0.035 314 5 cubic foot. Aprx. $\frac{7}{2} \div 100$	2.547 9525
"	=	0.028 377 4 bushel (U.S.). Aprx. $\frac{2}{7} \div 10$	2.452 9729
"	=	0.027 496 9 bushel (Brit.). Aprx. $1\frac{1}{4} \div 100$	2.439 2841
"	=	0.01 hectoliter.....	2.000 0000
"	=	0.001 307 94 cubic yard. Aprx. $\frac{4}{3} \div 1\ 000$	3.116 5887
"	=	0.001 cubic meter.....	3.000 0000
1 ton (short)	=	32.036 7 cubic feet. Aprx. 32.....	1.505 6480
"	=	9.071 85 hectoliters. Aprx. 9.....	0.957 6958
"	=	1.186 55 cubic yards. Aprx. $\frac{6}{5}$	0.074 2845
"	=	0.907 185 cubic meter. Aprx. $\frac{9}{10}$	1.957 6958
1 ton (netric)	=	35.314 5 cubic feet. Aprx. $\frac{7}{2} \times 10$	1.547 9525
"	=	10. hectoliters.....	1.000 0000
"	=	1.307 94 cubic yards. Aprx. $\frac{4}{5}$	0.116 5887
"	=	1. cubic meter.....	0.000 0000
1 ton (long)	=	35.881 1 cubic feet. Aprx. $\frac{4}{11} \times 100$	1.554 8663
"	=	10.160 5 hectoliters. Aprx. 10.....	1.006 9138
"	=	1.328 93 cubic yards. Aprx. $\frac{4}{5}$	0.123 5025
"	=	1.016 05 cubic meters. Aprx. 1.....	0.006 9138

ENERGY; WORK; HEAT; VIS-VIVA; TORQUE.

(Force $\times$ length; mass $\times$ temperature; elec. quant. $\times$ e. m. f.)

All energy units or measures are here grouped together, be they mechanical, electrical, thermal, chemical, kinetic, potential, etc. Units of power, not being energy but *rate* of energy, are not included in this group (see note under units of Power). For the relations between energies stated in terms of power units, as horse-power-hours, and kilowatt-hours, see the relations between horse-powers and kilowatts under Power.

The relations between the mechanical and thermal units of energy are based on the mechanical equivalent of heat; those between the mechanical and electric or absolute units are based on the value of gravity; those between the thermal and the electrical or absolute units are based on the specific heat of water in absolute units. These three bases are the three connecting links between these three classes of energy units. The three links are again interlinked by the relation that the mechanical equivalent of heat multiplied by gravity is equal to the specific heat of water, when all three are reduced to grams, centimeters, and seconds. This will be found explained more fully under Inter-relations of Units in the Introduction.

Torque is a force multiplied by a lever-arm; it is a "moment" and is therefore measured in units like foot-pounds or kilograms-meters; the relation between units of torque are therefore the same as those in the table between the same named units of energy. In order to show whether torque or energy is meant by such similarly named units, it has become customary to reverse the accepted term whenever torque is meant; that is, to use the term *pound-feet* for torque and *foot-pounds* for energy; also *meter-kilograms* for torque and *kilogram-meters* for energy; this distinction is to be recommended even though the length factor unfortunately comes first in foot-pounds of energy and last in kilogram-meters of energy. For the relations between units of torque and units of energy, see the end of the following table. Torque multiplied by an angle is energy, and as an angle has no dimensions, it follows that the dimensions of torque and of energy are the same, notwithstanding the fact that there is no direct equivalent between a foot-pound of torque, for instance, and a calorie of energy. If the torque is measured statically it is performing no work, yet it is a true torque; it is then like a suspended weight which is capable of doing work when released; but this weight (force) must be multiplied by a length or distance through which it acts in order to give energy, while torque already includes this factor length; this apparent discrepancy arises from the fact that an angle, by which torque must be multiplied to reduce it to energy, has no dimensions. In units of energy the length factor is in the direction of the force, while in units of torque it is perpendicular to the force. The two lengths are, therefore, at relatively different angles with each other, which explains how the angle enters into the difference in the nature of the two units; torque differs from energy somewhat like the so-called "wattless component" differs from the true energy in electrical quantities. See also the relations given at the end of the following table.

Mechanical Equivalent of Heat, and the Heat Unit. The mechanical equivalent of heat, sometimes called Joule's equivalent, is an empirical number which gives the relation that heat units bear to mechanical units, thus enabling one to calculate how much mechanical energy stated in foot-pounds, kilogram-meters, horse-power-hours, etc., is equal to any given amount of heat energy stated in calories or thermal units, or the reverse.

The mechanical units are all based on the C. G. S. or absolute system of units and on the acceleration of gravity, while the heat units are based on an inherent property of water, and on the thermometer scale and kind of thermometer. The two bases are therefore entirely different, and the relation between them, namely, the mechanical equivalent of heat, therefore is, and must always remain, one that has to be determined by experiment. Moreover, these experiments are intricate and the heat units themselves are not yet definitely and accurately established, owing to the variations in the specific heats of water between 0° and 100° C. and to the differences in the kinds of thermometers; therefore the mechanical equivalent of heat

is not yet known to very great accuracy, although the accuracy is quite sufficient for all purposes except perhaps for very refined physical research. Quite a number of researches have been made, among which are a few very accurate ones, but the most authoritative value is unquestionably the one recommended by Griffiths and by Ames in their reports to the International Physical Congress of 1900, which met in Paris (*Rapports, Congrès International de Physique, 1900, tome 1, pp. 226 and 204*). Griffiths there concludes, after a careful comparison and discussion of the best determinations, to recommend the number 4.187 joules for the calorific capacity (more generally called the specific heat) of 1 gram of water raised from 15° to 16° C., measured on the hydrogen scale of the International Bureau. The probable error, he says, is less than 1 in 2000. He also recommends that this be considered the same as the mean value per degree between 0° and 100° C., and believes it to be very improbable that the error in this assumption attains 2 in 1000. This therefore also defines the unit of heat which he recommends as the intermediate thermic standard. The value which he recommends, 4.187, agrees with that given as the most probable in the report of Ames, after reduction to the same temperature interval. In Ames' report all the important determinations of the mechanical equivalent of heat are discussed and compared. This value is the mean of the determinations of Rowland, Griffiths, Schuster, and Gannon, and Callender and Barnes, when all their results are reduced to the hydrogen scale of temperature and when the electrical methods are corrected for the probable error of the present international volt as now legally fixed in terms of the Clark cell.

Taking for the value of gravity at sea-level and at 45° latitude 9.805 966 in meters (Helmert, *Die math. u. phys. Theorien der hohen Geodäsie*, II, p. 241, 1884), this specific heat reduces to 426.985 kilogram-meters as the value of the mechanical equivalent of heat. According to Griffiths' probable error, the true value therefore lies between 427.20 and 426.77 kilogram-meters, showing that the fourth figure is still uncertain. Some recent, very carefully made researches by Barnes, which were not finished in time to be included in Griffiths' report, give the value 426.6, and it is probable, therefore, that the true value is lower than Griffiths' probable mean, rather than higher, and may be even nearer to 426.6 than to 426.985. But as the final value in Griffiths' report may be considered as semi-official, the author has adopted that value throughout this book, except that in order to make it approach rather than depart from Barnes' value, it has been abbreviated to 426.9 instead of 427.0. In view of the fact that the fourth place is still uncertain it would not be rational to retain more than four places of figures.

This naturally also establishes the absolute value of the heat units and of the mean specific heat of water to be used in this book. The value of the specific heat of water in absolute units is the same thing as the mechanical equivalent of heat stated in ergs or joules. The specific heat of water is different at different temperatures between 0° and 100° C., but the value between 15° and 16° C. (according to Barnes at 16° C.) is as nearly as has been determined equal to the mean per degree for the whole value between 0° and 100° C., and a heat unit based on this mean is therefore much more definitely defined than if based merely on a rise of temperature of one degree without stating which degree.

Although it would perhaps be more rational to consider the specific heat of water to be the fundamental quantity, the mechanical equivalent of heat being then derived from it, yet the author has reversed this by adopting a more simple abbreviated number for the mechanical equivalent, and letting the specific heat be the incommensurable, derived quantity. This was done because the former is used very frequently, while the latter is not. The uncertainty of the fourth place of figures in either of these values, which may be ± 2 , does not warrant any fine distinction between the fundamental and the derived value. The resulting value of the specific heat of water then becomes 4.186 17 instead of 4.187. In view of the researches of Barnes above mentioned, the former value is probably even more nearly correct than the latter.

The value of the mechanical equivalent of heat and that of the calorie or heat unit adopted in this book, are therefore given by the following statements: 426.9 kilogram-meters of energy will raise 1 kilogram of water from 15° to 16° C., hydrogen scale, at sea-level, latitude 45° , and are there-

fore equivalent to one large calorie or kilogram calorie. The small calorie or gram calorie, equal to one thousandth of the large calorie, is the amount of heat that will raise the temperature of 1 gram of water from 15° to 16° C., hydrogen scale; this is taken as equal to one hundredth of the amount of heat that will raise the temperature of 1 gram of water from 0° to 100° C. Unfortunately writers generally do not state which of the two calories they mean. The **thermal unit**, or British thermal unit, or BTU, is the amount of heat which will raise one pound (av.) of water one degree Fahrenheit; in these tables it is a derived unit whose value is determined from that of either of the calories. The hybrid unit based on the pound and the Centigrade scale has no name.

This mechanical equivalent, namely 426.9 kilogram-meters per kilogram Centigrade heat unit, corresponds to 778.104 foot-pounds per pound Fahrenheit heat unit or per thermal unit. The probable error in them is thought to be within 1 in 2 000. For further equivalents or conversions factors based on this, see the table.

ENERGY; WORK; HEAT; VIS-VIVA; TORQUE.

Aprx. means within 2%.

	Logarithm
1 erg or dyne-centimeter [dyne-cm]:	
= 0.001 019 79 gram-centimeter. Aprx. $\frac{1}{4} \div 1000$	3.008 5096
= 0.000 516 328 foot-grain. Aprx. $\frac{3}{16} \div 10\ 000$	4.712 9260
= 0.000 000 1 joule	7.000 0000
= 0.000 000 073 761 2 foot-pound. Aprx. $\frac{3}{4} \div 10\ 000\ 000$...	8.867 8279
1 gram-centimeter [g-cm]:	
= 980.596 6 ergs. Apr. 1 000.	2.991 4904
= 0.000 098 059 66 joule. Aprx. $\frac{1}{10} \div 1000$	5.991 4904
= 0.000 072 330 0 foot-pound. Aprx. $\frac{5}{7} \div 10\ 000$	5.859 3184
= 0.000 01 kilogram-meter.....	5.000 0000
1 foot-grain [ft-gr]:	
= 1 936.75 ergs. Aprx. 1900.....	3.287 0740
= 1.975 08 gram-centimeters. Aprx. 2.....	0.295 5836
= 0.000 193 675 joule. Aprx. $19 \div 100\ 000$	4.287 0740
= 0.000 142 857 ft.-lb. Aprx. $\frac{1}{7} \div 1\ 000$	4.154 9020
1 joule [j] or volt-coulomb or watt-second [w-s]:	
= 10 000 000. ergs.....	7.000 0000
= 10 197.9 gram-centimeters. Aprx. 10 000.....	4.008 5096
= 0.737 612 foot-pound. Aprx. $\frac{3}{4}$	1.867 8279
= 0.238 882 small calorie. Aprx. $24 \div 100$	1.378 1834
= 0.101 979 kilogram-meter. Aprx. $\frac{1}{10}$	1.008 5096
= 0.001 359 72 metric hp-second. Aprx. $\frac{1}{8} \div 1\ 000$	3.133 4483
= 0.001 341 11 horse-power-second. Aprx. $\frac{4}{3} \div 1\ 000$	3.127 4653
= 0.001 kilowatt-second. Aprx. $\frac{1}{4} \div 1000$	3.000 0000
= 0.000 947 960 thermal unit. Aprx. $95 \div 100\ 000$	4.976 7901
= 0.000 526 645 pound-Centgr. heat unit. Aprx. $\frac{1}{19} \div 100$	4.721 5176
= 0.000 277 778 watt-hour. Aprx. $\frac{3}{11} \div 1\ 000$	4.443 6975
= 0.000 238 882 large calorie. Aprx. $24 \div 100\ 000$	4.378 1834
1 foot-pound [ft.-lb]:	
= 13 557 300. ergs. Aprx. $2\frac{1}{2} \times 1\ 000\ 000$	7.132 1721
= 13 825.5 gram-centimeters. Aprx. $\frac{7}{6} \times 10\ 000$..	4.140 6817
= 1.355 73 joules. Aprx. $\frac{4}{3}$	0.132 1721
= 0.323 859 small calorie. Aprx. $\frac{13}{40}$	1.510 3555
= 0.138 255 kilogram-meter. Aprx. $\frac{7}{60}$	1.140 6817
= 0.001 843 40 metric hp-second. Aprx. $\frac{1}{6} \div 1\ 000$...	3.265 6204
= 0.001 818 18 horse-power-second. Aprx. $\frac{2}{11} \div 100$..	3.259 6373
= 0.001 355 73 kilowatt-second. Aprx. $\frac{4}{3} \div 1\ 000$	3.132 1721
= 0.001 285 17 thermal unit. Aprx. $\frac{9}{7} \div 1\ 000$	3.108 9622
= 0.000 713 986 lb-Centgr. heat unit. Aprx. $\frac{5}{7} \div 1\ 000$..	4.853 6897
= 0.000 376 591 watt-hour. Aprx. $\frac{3}{8} \div 1\ 000$	4.575 8696
= 0.000 323 859 large calorie. Aprx. $\frac{13}{4} \div 10\ 000$	4.510 3555
= 0.000 000 505 051 horse-power-hour. Aprx. $\frac{1}{2} \div 1\ 000\ 000$	7.703 3348
= 0.000 000 376 591 kilowatt-hour. Aprx. $\frac{3}{8} \div 1\ 000\ 000$...	7.575 8696

1 meter-kilogram: see kilogram-meter; also under *torque*, below.

1 kilogram-meter [kg-m]:

=	98 059 660. ergs.	Aprx. 100 000 000.....	7.991 4904
=	100 000. gram-centimeters.....		5.000 0000
=	9.805 966 joules.	Aprx. 10.....	0.991 4904
=	7.233 00 foot-pounds.	Aprx. $\frac{89}{11}$	0.859 3184
=	2.342 47 small calories.	Aprx. $\frac{7}{8}$	0.369 6738
=	0.013 333 3 metric hp-second.	Aprx. $\frac{4}{3} + 100$	2.124 9387
=	0.013 150 9 horse-power-second.	Aprx. $\frac{4}{3} + 100$	2.118 9557
=	0.009 805 966 kilowatt-second.	Aprx. $\frac{1}{100}$	3.991 4904
=	0.009 295 67 thermal unit.	Aprx. $2\frac{2}{3} + 1 000$	3.968 2805
=	0.005 164 26 lb-Centgr. heat unit.	Aprx. $52 + 10 000$	3.713 0080
=	0.002 723 88 watt-hour.	Aprx. $\frac{3}{11} + 100$	3.435 1879
=	0.002 342 47 large calorie.	Aprx. $\frac{7}{8} + 1 000$	3.369 6738
=	0.000 003 703 70 metric hp-hour.	Aprx. $\frac{3}{8} + 100 000$	6.568 6362
=	0.000 002 723 88 kilowatt-hour.	Aprx. $\frac{3}{11} + 100 000$	6.435 1879

1 metric horse-power-second [hp-s]:

=	735.447 joules.	Aprx. $\frac{3}{4} \times 1 000$	2.866 5517
=	542.475 foot-pounds.	Aprx. $\frac{1}{2} \times 100$	2.734 3797
=	175.685 small calories.	Aprx. $\frac{7}{8} \times 100$	2.244 7351
=	75. kilogram-meters.	Aprx. $\frac{3}{4} \times 100$	1.875 0613
=	0.204 291 watt-hour.	Aprx. $204 \div 1 000$	1.310 2492

1 horse-power-second [hp-s]:

=	745.650 joules.	Aprx. $\frac{3}{4} \times 1 000$	2.872 5348
=	550. foot-pounds or $\frac{1}{2} \times 100$		2.740 3627
=	178.122 small calories.	Aprx. $\frac{5}{8} \times 100$	2.250 7182
=	76.040 4 kilogram meters.	Aprx. $\frac{3}{4} \times 100$	1.881 0444
=	0.207 125 watt-hour.	Aprx. $207 \div 1 000$	1.316 2323

1 kilowatt-second [kw-s]:

=	1 000. joules.		3.000 0000
=	737.612 foot-pounds.	Aprx. $\frac{3}{4} \times 1 000$	2.867 8279
=	238.882 small calories.	Aprx. 240.....	2.378 1834
=	101.979 kilogram-meters.	Aprx. 100.....	2.008 5096
=	0.277 778 watt-hour.	Aprx. $\frac{1}{40}$	1.443 6975

1 calorie (small) [cal] or gram-Centigrade heat unit [g-C]:

=	0.001 large calorie or kg-Centgr. heat unit, which see....		3.000 0000
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1 thermal unit [BTU] or pound-Fahrenheit heat unit† [lb-F]:

=	1 054.90 joules.	Aprx. $2\frac{1}{2} \times 100$	3.023 2099
=	778.104 foot-pounds.	Aprx. $\frac{7}{8} \times 1 000$	2.891 0379
=	251.996 small calories.	Aprx. $\frac{1}{4} \times 1 000$	2.401 3933
=	107.577 kilogram-meters.	Aprx. 108.....	2.031 7195
=	1.434 36 metric horse-power-seconds.	Aprx. $1\frac{9}{7}$	0.156 6582
=	1.414 74 horse-power-seconds.	Aprx. $1\frac{9}{7}$	0.150 6752
=	1.054 90 kilowatt-seconds.	Aprx. add $\frac{1}{20}$	0.023 2099
=	0.555 556 pound-Centgr. heat unit.	Aprx. $\frac{5}{9}$	1.744 7275
=	0.293 027 watt-hour.	Aprx. $\frac{5}{17}$	1.466 9074
=	0.251 995 8 large calorie.	Aprx. $\frac{1}{4}$	1.401 3933
=	0.000 398 433 metric hp-hour.	Aprx. $4 \div 10 000$	4.600 3557
=	0.000 392 982 horse-power-hour.	Aprx. $4 \div 10 000$	4.594 3727
=	0.000 293 027 kilowatt-hour.	Aprx. $8\frac{8}{9} \div 100 000$	4.466 9074

1 pound-Centigrade heat unit [lb-C]:

=	1 898.81 joules.	Aprx. 1 900.....	3.278 4824
=	1 400.59 foot-pounds.	Aprx. 1 400.....	3.146 3104
=	453.592 4 small calories.	Aprx. $\frac{9}{2} \times 100$	2.656 6658
=	193.639 kilogram-meters.	Aprx. 194.....	2.286 9920
=	2.581 85 metric horse-power-seconds.	Aprx. $3\frac{1}{12}$	0.411 9307
=	2.546 52 horse-power-seconds.	Aprx. $1\frac{9}{4}$	0.405 9477
=	1.898 81 kilowatt-seconds.	Aprx. $1\frac{9}{10}$	0.278 4824
=	1.800 00 thermal units.	Aprx. $\frac{9}{5}$	0.255 2725
=	0.527 448 watt-hour.	Aprx. $1\frac{10}{19}$	1.722 1799
=	0.453 592 4 large calorie.	Aprx. $1\frac{1}{22}$	1.656 6658
=	0.000 717 180 metric hp-hour.	Aprx. $\frac{5}{7} \div 1 000$	4.855 6282
=	0.000 707 368 horse-power-hour.	Aprx. $\frac{5}{7} \div 1 000$	4.849 6452
=	0.000 527 448 kilowatt-hour.	Aprx. $\frac{1}{19} \div 100$	4.722 1799

† Often called a British Thermal Unit. BTU also means kilowatt-hour.

1 watt-hour [w-h]:

=	3 600.	joules.....	3.556 3025
=	2 655.40	foot-pounds. Aprx. $\frac{8}{3} \times 1\ 000$	3.424 1305
=	859.975	small calories. Aprx. $\frac{9}{7} \times 1\ 000$	2.934 4859
=	367.123	kilogram-meters. Aprx. $\frac{11}{3} \times 100$	2.564 8121
=	4.894 98	metric horse-power-seconds. Aprx. $\frac{49}{10}$	0.689 7508
=	4.828 01	horse-power-seconds. Aprx. $\frac{48}{10}$	0.683 7678
=	3.6	kilowatt-seconds. Aprx. $\frac{36}{10}$ or $\frac{40}{11}$	0.556 3025
=	3.412 66	thermal units. Aprx. $\frac{34}{10}$ or $\frac{17}{5}$	0.533 0926
=	1.895 92	pound-Centigr. heat units. Aprx. $\frac{19}{10}$	0.277 8201
=	0.859 975	large calorie. Aprx. $\frac{6}{7}$	1.934 4859
=	0.001 359 72	metric horse-power-hour. Aprx. $\frac{4}{3} \div 1\ 000$..	3.133 4483
=	0.001 341 11	horse-power-hour. Aprx. $\frac{4}{3} \div 1\ 000$	3.127 4652
=	0.001	kilowatt-hour.....	3.000 0000

1 calorie (large) [Cal] or kilogram-Centigrade heat unit [kg-C]:

=	4 186.17	joules. Aprx. 4200.....	3.621 8166
=	3 087.77	foot-pounds. Aprx. 3 100.....	3.489 6446
=	1 000.	small calories..	3.000 0000
=	426.900	kilogram-meters. Aprx. $\frac{3}{4} \times 1\ 000$	2.630 3262
=	5.692	metric horse-power seconds. Aprx. $\frac{40}{7}$	0.755 2649
=	5.614 12	horse-power-seconds. Aprx. $\frac{40}{7}$	0.749 2819
=	4.186 17	kilowatt-seconds. Aprx. $\frac{42}{10}$	0.621 8166
=	3.968 32	thermal units. Aprx. 4.....	0.598 6067
=	2.204 62	pound-Centgr. heat units. Aprx. $\frac{22}{10}$	0.343 3342
=	1.162 82	watt-hours. Aprx. $\frac{7}{6}$	0.065 5141
=	0.001 581 11	metric horse-power-hour. Aprx. $\frac{8}{5} \div 1\ 000$.	3.198 9624
=	0.001 559 48	horse-power-hour. Aprx. $\frac{11}{7} \div 1\ 000$	3.192 9794
=	0.001 162 82	kilowatt-hour. Aprx. $\frac{7}{6} \div 1\ 000$	3.065 5141

1 mile-pound [ml-lb]:

=	5 280.	foot-pounds. Aprx. 5 300.....	3.722 6339
=	0.002 703 66	metric horse-power-hour. Aprx. $\frac{8}{3} \div 1\ 000$.	3.431 9518
=	0.002 666 67	horse-power-hour. Aprx. $\frac{8}{3} \div 1\ 000$	3.425 9687
=	0.001 988 40	kilowatt-hour. Aprx. $\frac{2}{1\ 000}$	3.298 5035

1 kilogram-kilometer [kg-km]:

=	7 233.00	foot-pounds. Aprx. $\frac{5}{7} \times 10\ 000$	3.859 3184
=	1 000.	kilogram-meters.....	3.000 0000
=	1.369 89	mile-pounds. Aprx. $\frac{1}{8}$	0.136 6845
=	0.003 703 70	metric horse-power-hour. Aprx. $\frac{3}{8} \div 100$..	3.568 6362
=	0.003 653 03	horse-power-hour. Aprx. $\frac{11}{3} \div 1\ 000$	3.562 6532
=	0.002 723 88	kilowatt-hour. Aprx. $\frac{11}{4} \div 1\ 000$	3.435 1879

1 metric horse-power-minute [hp-m]:

=	44 126.8	joules. Aprx. $\frac{4}{5} \times 100\ 000$	4.644 7029
=	32 548.5	foot-pounds. Aprx. $\frac{13}{4} \times 10\ 000$	4.512 5309
=	4 500.	kilogram-meters. Aprx. $\frac{9}{2} \times 1\ 000$	3.653 2125
=	12.257 5	watt-hours. Aprx. $\frac{110}{9}$	1.088 4004
=	10.541 1	large calories. Aprx. $\frac{21}{2}$	1.022 8863

1 horse-power-minute [hp-m]:

=	44 739.0	joules. Aprx. $\frac{4}{5} \times 100\ 000$	4.650 6860
=	33 000.	foot-pounds. Aprx. $\frac{1}{3} \times 100\ 000$	4.518 5139
=	4 562.42	kilogram-meters. Aprx. $\frac{9}{2} \times 1\ 000$	3.659 1956
=	12.427 5	watt-hours. Aprx. $\frac{50}{4}$	1.094 3835
=	10.687 3	large calories. Aprx. $\frac{107}{10}$	1.028 8694

1 kilowatt-minute [kw-m]:

=	60 000.	joules.....	4.778 1513
=	44 256.7	foot-pounds. Aprx. $\frac{4}{5} \times 100\ 000$	4.645 9793
=	6 118.72	kilogram-meters. Aprx. 6 000.....	3.786 6609
=	16.666 7	watt-hours. Aprx. $\frac{1}{6} \times 100$	1.221 8488
=	14.332 9	large calories. Aprx. $\frac{1}{7} \times 100$	1.156 3347

1 metric horse-power-hour [hp-h]:

= 2 647 610. joules. Aprx. $\frac{3}{8} \times 1\,000\,000$	6.422 8542
= 1 952 910. foot-pounds. Aprx. $\frac{1}{51} \times 100\,000\,000$	6.290 6822
= 270 000. kilogram-meters. Aprx. $27 \times 10\,000$	5.431 3638
= 3 600. metric horse-power-seconds.....	3.556 3025
= 2 509.83 thermal units. Aprx. $\frac{1}{4} \times 10\,000$	3.399 6443
= 1 394.35 pound-Centgr. heat units. Aprx. 1 400.....	3.144 3718
= 735.447 watt-hours. Aprx. 740.....	2.866 5517
= 632.467 large calories. Aprx. 630.....	2.801 0376
= 270. kilogram-kilometers.....	2.431 3638
= 60. metric horse-power-minutes.....	1.778 1513
= 0.986 318 horse-power-hour. Aprx. 1.....	1.994 0170
= 0.735 447 kilowatt-hour. Aprx. $\frac{3}{4}$ or $\frac{2}{3}$	1.866 5517

1 horse-power-hour [hp-h]:

= 2 684 340. joules. Aprx. $\frac{8}{9} \times 1\,000\,000$	6.428 8373
= 1 980 000. foot-pounds. Aprx. 2 000 000.....	6.296 6652
= 273 745. kilogram-meters. Aprx. $\frac{1}{4} \times 100\,000$	5.437 3469
= 3 600. horse-power-seconds.....	3.556 3025
= 2544.65 thermal units. Aprx. $\frac{1}{4} \times 10\,000$	3.405 6274
= 1 413.69 pound-Centgr. heat units. Aprx. 1 400.....	3.150 3549
= 745.650 watt-hours. Aprx. $\frac{3}{4} \times 1\,000$	2.872 5348
= 641.240 large calories. Aprx. 640.....	2.807 0207
= 375.000 mile-pounds or $\frac{3}{8} \times 1\,000$	2.574 0313
= 60. horse-power-minutes.....	1.778 1513
= 1.013 87 metric horse-power-hours. Aprx. 1.....	0.005 9830
= 0.745 650 kilowatt-hour. Aprx. $\frac{3}{4}$	1.872 5348

1 kilowatt-hour [kw-h] [BTU]†:

= 3 600 000. joules.....	6.556 3025
= 2 655 403. foot-pounds. Aprx. $\frac{8}{9} \times 1\,000\,000$	6.424 1305
= 367 123. kilogram-meters. Aprx. $\frac{1}{3} \times 100\,000$	5.564 8121
= 4 828.01 horse-power-seconds. Aprx. 4 800.....	3.683 7678
= 3 412.66 thermal units. Aprx. 3 400.....	3.533 0926
= 1 895.92 pound-Centgr. heat units. Aprx. 1 900.....	3.277 8201
= 1 000. watt-hours.....	3.000 0000
= 859.975 large calories. Aprx. $\frac{9}{10} \times 1\,000$	2.934 4859
= 502.917 mile-pounds. Aprx. $\frac{1}{2} \times 1\,000$	2.701 4966
= 367.123 kilogram-kilometers. Aprx. $\frac{1}{3} \times 100$	2.564 8121
= 60. kilowatt-minutes.....	1.778 1513
= 1.359 72 metric horse-power-hours. Aprx. add $\frac{1}{2}$	0.133 4483
= 1.341 11 horse-power-hours. Aprx. add $\frac{1}{2}$	0.127 4652

Conversion Tables for Energy, Work, Heat.

Foot-lbs.=	kg-mets	thermal u						
Klgr-met's	ft-lbs.			ft-lbs.	calories			
Thermal u.					(large)	kg-mt		
Calories (l)								joules
Calories (s)								
Joules =							calories	
							(small)	
1	0.138 26	7.2330	0.001 285 2	778.10	0.002 342 5	426.90	0.238 88	4.1862
2	0.276 51	14.466	0.002 570 3	1 556.2	0.004 684 9	853.80	0.477 76	8.3723
3	0.414 77	21.699	0.003 855 5	2 334.3	0.007 027 4	1 280.7	0.716 65	12.559
4	0.553 02	28.932	0.005 140 7	3 112.4	0.009 369 9	1 707.6	0.955 53	16.745
5	0.691 28	36.165	0.006 425 9	3 890.5	0.011 712	2 134.5	1.194 4	20.931
6	0.829 53	43.398	0.007 711 0	4 668.6	0.014 055	2 561.4	1.433 3	25.117
7	0.967 79	50.631	0.008 996 2	5 446.7	0.016 397	2 988.3	1.672 2	29.303
8	1.106 0	57.864	0.010 281	6 224.8	0.018 740	3 415.2	1.911 1	33.489
9	1.244 3	65.097	0.011 567	7 002.9	0.021 082	3 842.1	2.149 9	37.676
10	1.382 6	72.330	0.012 852	7 781.0	0.023 425	4 269.0	2.388 8	41.862

† In Great Britain this is often called a Board of Trade Unit, or simply a Unit, and is abbreviated to BTU; these letters also stand for a British Thermal Unit, which has an entirely different value.

RELATIONS BETWEEN TORQUE AND ENERGY.

Let **foot-pounds**, **kilogram-meters**, etc., represent units of **energy**, and let **pound-feet**, **meter-kilograms**, etc., represent units of **torque**; a radian is the angle whose arc is equal to its radius (about $57\frac{1}{2}^\circ$); torque acting through an angle gives energy; the general relations between the units then are:

units of **energy** = units of **torque** $\times$ radians;

units of **torque** = units of **energy** $\div$ radians.

The numerical relations between the units bearing similar names are:

1 foot-pound [ft-lb]	=	1 pound-foot-radian ;
1 pound-foot [lb-ft]	=	1 foot-pound per radian;
1 foot-pound	=	0.159 155 pound-foot-revolution ;
1 pound-foot	=	6.283 19 foot-pounds per revolution;
1 foot-pound per revolution	=	0.159 155 pound-foot ;
1 pound-foot-revolution	=	6.283 19 foot-pounds .

The same relations are true between **kilogram-meters** of **energy** and **meter-kilograms** of **torque**, or between any other pairs of units having similar names.

TRACTION ENERGY.

Ton-mile. A unit used in traction calculations representing the energy (work, not power) which is required to draw one (short) ton of 2 000 lbs. over a distance of one mile. It has no fixed value, being dependent upon the nature of the track, the grade, and the speed. It is never used similarly to the term "foot-pound" as representing one ton raised one mile vertically. See also note on "pound per ton" under tractive effort, below.

Ton-kilometer. A unit similar to "ton-mile," but meaning one metric ton drawn over a distance of one kilometer.

Ton per mile. A term popularly (though not correctly) used for "ton-mile" (see above). The term "per" is here used incorrectly, as in all other cases it means that the first quantity is *divided* by the second, and not multiplied, as in this case.

Car-mile. A term used in traction calculations representing the energy required to draw a car one mile. It is analogous to ton-mile (see above), but is even less fixed in value, as it also involves the weight of the car.

The only fixed relations which these units have are the following:

		Logarithm
1 ton-kilometer [t-km]	= 0.684 943 ton-mile . Aprx. $\frac{1}{10}$	1.835 6545
1 ton-mile [tn-mi]	= 1.459 98 ton-kilometer . Aprx. $\frac{1}{10}$...	0.164 3455
(Aprx. means within 2%.)		

TRACTION FORCE; TRACTIVE EFFORT; TRACTION RESISTANCE; TRACTION COEFFICIENT. (Force $\div$ weight.)

The following units, although really of the nature of forces, have been placed here in order to accompany traction energy.

Pound per ton. A unit used in traction calculations, representing the force in pounds required to move one (short) ton of 2 000 pounds *horizontally* against the friction of the rails, wheels, roads, etc. It has no fixed value, as it varies with this friction. It is really a mere coefficient, relation, or mere number, and has no dimensional formula. See also note on "ton-mile" under Energy units.

Kilogram per ton. A unit similar to "pound per ton," but meaning the force in kilograms required to draw one metric ton.

The only fixed relations which these units have are the following:

		Logarithm
1 pound per (short) ton [lb/tn]:	= 0.500 000 kg per (met.) tn .	1.698 9700
1 kilogram per (met.) ton [kg/t]	= 2.000 000 lb per (short) ton .	0.301 0300

POWER; RATE of ENERGY; RATE of DOING WORK; MOMENTUM. (Energy $\div$ time; mass $\times$ velocity.)

Units of power are for measuring the *rate* of doing work, and should therefore be clearly distinguished from the units of work or heat, which are *energy* and not power. Much confusion is often caused by confounding these two terms with each other. Power bears the same relation to energy (work, heat, etc.) as a velocity does to length; power is energy divided by time, just as velocity is length divided by time. A reduction from power to energy or the reverse therefore always involves the factor of time.

There are really only two true power units in common use—the horse-power and the watt (or kilowatt)—but powers are also often expressed in energy per unit of time, as in foot-pounds per minute. This table of reduction factors is confined in general to the true power units. A large number of reduction factors in terms of units of energy have, however, also been included, but these are in general given here only *per minute* and not also per second and per hour, as this would have made the table many times as long and very cumbersome to use; a mere multiplication or division by 60 will then reduce the energy per minute to its equivalent in energy per hour or per second, respectively.

In such cases confusion may arise as to whether one should multiply or divide by 60, owing to the difference between a unit and a quantity measured in terms of that unit; the following general reduction factors will avoid all such confusion:

If W is any unit of energy (such as work or heat) like a foot-pound, heat unit, etc., then

$$\begin{aligned} 1 \text{ } W \text{ per hour} &= \frac{1}{60} W \text{ per minute;} \\ &= \frac{1}{3600} W \text{ per second;} \\ 1 \text{ } W \text{ per minute} &= 60 W \text{ per hour;} \\ &= \frac{1}{60} W \text{ per second;} \\ 1 \text{ } W \text{ per second} &= 3600 W \text{ per hour;} \\ &= 60 W \text{ per minute.} \end{aligned}$$

Thus $120 \text{ ft-lbs per min} = (120 \times 60) = 7200 \text{ ft-lbs per hour}$ or $(120 \div 60) = 2 \text{ ft-lbs per sec.}$

For reducing powers which are expressed in energy units per *minute* (like ft-lbs per min) to powers expressed in other energy units, but also per *minute* (like heat units per min) use the table for the energy units (ft-lbs into heat units in this case); the element of *time* then does not enter, as it is the same in both. If one is per minute and the other per second, they must, of course, both be first reduced to either minutes or seconds.

Some of these same units also measure **momentum**, only that they then mean masses multiplied by velocities. In the units of power the pounds, kilograms, etc., represent forces, while in the units of momentum they represent masses.

Power factor is a term used to show the amount of true power contained in a given amount of apparent power. It is the ratio of the true power to the apparent power. Its use is limited chiefly to electric power generated by alternating currents. With direct electric currents the power is equal to the product of the volts and the amperes, and is called watts; with alternating currents, however, this is true only when the volts and amperes are exactly in phase with each other, which often is not the case. When there is such a difference in phase, that is, when the current lags behind or precedes the voltage, their product is only apparent power and is usually measured in volt-amperes. If the true power in such a case is measured in watts, then the power factor will be the number of watts divided by the number of volt-amperes, and it will always be less than unity, in practice usually between about 0.7 and 0.95. For true sine waves the real power in watts is equal to the voltage $\times$ current $\times \cos \phi$, in which ϕ is the angular phase difference; hence it follows that in such cases the power factor is numerically equal to $\cos \phi$, which is found directly from a table of cosines. Sometimes the power factor is stated in percent, in which case it is equal to the above figure multiplied by 100.

Load factor is a term commonly applied to electric, steam, or hydraulic power stations to show how much of the total possible amount of power has actually been generated or used during a limited time. It is the ratio of the mean power used during a limited time (generally 1 day) divided by the total power that the station could have generated during that time; as it is usually stated in percent, this ratio must be multiplied by 100. If the average power generated during a day is $\frac{1}{4}$ of that which the station is capable of generating, the load factor is 25%. A 100% load factor means that the station is running at its full output all the time. In water-power installations or in stations having storage batteries, this quantity is of use in determining the amount of storage capacity desired.

POWER; RATE of ENERGY; RATE of DOING WORK; MOMENTUM.

Aprx. means within 2%.

	Logarithm
1 erg per second or 1 dyne-centimeter per second:	
= 0.000 000 1 watt.	7.000 0000
1 gram-centimeter per second [g-cm/s]:	
= 0.000 098 059 7 watt. Aprx. $\frac{1}{10\ 000}$	5.991 4904
1 foot-grain per second [ft-gr/s]:	
= 0.000 193 675 watt. Aprx. $\frac{1}{51} \div 100$	4.287 0740
1 foot-pound per minute [ft-lb/min]:	
= 0.022 595 4 watt. Aprx. $\frac{1}{4} \div 100$	2.354 0208
= 0.011 363 6 mile-pound per hour. Aprx. $\frac{8}{7} \div 100$	2.055 5174
= 0.000 030 723 4 metric horse-power. Aprx. $\frac{4}{13} \div 10\ 000$	5.487 4691
= 0.000 030 303 0 horse-power. Aprx. $3 \div 100\ 000$	5.481 4860
= 0.000 022 595 4 kilowatt. Aprx. $\frac{1}{4} \div 100\ 000$	5.354 0208
1 calorie (small) per minute [cal/min]:	
= 0.069 769 5 watt. Aprx. $\frac{7}{100}$	2.843 6653
1 kilogram-meter per minute [kg-m/min]:	
= 0.163 433 watt. Aprx. $\frac{1}{6}$	1.213 3391
= 0.082 193 2 mile-pound per hour. Aprx. $\frac{5}{6} \div 10$	2.914 8357
= 0.000 222 222 metric horse-power. Aprx. $\frac{2}{3} \div 1\ 000$	4.346 7875
= 0.000 219 182 horse-power. Aprx. $\frac{2}{3} \div 1\ 000$	4.340 8044
= 0.000 163 433 kilowatt. Aprx. $\frac{1}{6} \div 1\ 000$	4.213 3391
1 watt [w] or 1 joule per second:	
= 10 000 000. ergs per second.	7.000 0000
= 10 197.9 gram-centimeters per second. Aprx. $10\ 000$	4.008 5096
= 5 163.28 foot-grains per second. Aprx. $5\ 200$	3.712 9260
= 44.256 7 foot-pounds per minute. Aprx. $\frac{4}{5} \times 100$	1.645 9793
= 14.332 9 small calories per minute. Aprx. $\frac{1}{4} \times 100$	1.156 3347
= 6.118 72 kilogram-meters per minute. Aprx. 6	0.786 6609
= 0.737 612 foot-pound per second. Aprx. $\frac{3}{4}$	1.867 8279
= 0.502 917 mile-pound per hour. Aprx. $\frac{1}{2}$	1.701 4965
= 0.238 882 small calorie per second. Aprx. $24 \div 100$	1.378 1834
= 0.101 979 kilogram-meter per second. Aprx. $\frac{1}{10}$	1.008 5096
= 0.056 877 6 thermal unit per minute. Aprx. $\frac{4}{7} \div 10$	2.754 9414
= 0.031 598 7 lb-Centgr. heat unit per min. Aprx. $2\frac{2}{7} \div 100$	2.499 6889
= 0.014 332 9 large calorie per minute. Aprx. $\frac{1}{70}$	2.156 3347
= 0.001 359 72 metric horse-power. Aprx. $\frac{4}{3} \div 1\ 000$	3.133 4483
= 0.001 341 11 horse-power. Aprx. $\frac{4}{3} \div 1\ 000$	3.127 4653
= 0.001 kilowatt.	3.000 0000
watts = volt-amperes $\times$ cos angle of lag.	
volt-amperes = watts $\div$ cos angle of lag.	
1 foot-pound per second [ft-lb/s]:	
= 60. foot-pounds per minute.	1.778 1513
= 8.295 32 kilogram-meters per minute. Aprx. $\frac{5}{6} \times 10$	0.918 8330
= 1.355 73 watts. Aprx. $\frac{4}{3}$	0.132 1721
= 0.001 843 40 metric horse-power. Aprx. $1\frac{1}{6} \div 1\ 000$	3.265 6204
= 0.001 818 18 horse-power. Aprx. $\frac{3}{11} \div 100$	3.259 6373
= 0.001 355 73 kilowatt. Aprx. $\frac{4}{3} \div 1\ 000$	3.132 1721

1 mile-pound per hour

=	88. foot-pounds per minute. Aprx. $\frac{7}{8} \times 100$	1.944 4827
=	12.166 5 kilogram-meters per minute. Aprx. 12.....	1.085 1644
=	1.988 40 watts. Aprx. 2.....	0.298 5035
=	0.002 666 67 horse-power. Aprx. $\frac{8}{9} \div 1\ 000$	3.425 9687

1 calorie (small) per second [cal/s]=4.186 17 watts. Ap. $\frac{50}{12}$. 0.621 8166

1 kilogram-meter per second [kg-m/s]:

=	433.980 foot-pounds per minute. Aprx. $\frac{3}{4} \times 1\ 000$..	2.637 4696
=	60. kilogram-meters per minute.....	1.778 1513
=	9.805 97 watts. Aprx. 10.....	0.991 4904
=	0.013 333 3 metric horse-power. Aprx. $\frac{4}{3} \div 100$	2.124 9387
=	0.013 150 9 horse-power. Aprx. $\frac{4}{3} \div 100$	2.118 9557
=	0.009 805 97 kilowatt. Aprx. $1 \div 100$	3.991 4904

1 thermal unit per minute [lb-F/min]:

=	17.581 6 watts. Aprx. $\frac{7}{4} \times 10$	1.245 0586
=	0.023 906 0 metric horse-power. Aprx. $1\frac{1}{2} \div 100$	2.378 5069
=	0.023 578 9 horse-power. Aprx. $\frac{7}{3} \div 100$	2.372 5239
=	0.017 581 6 kilowatt. Aprx. $\frac{7}{4} \div 100$	2.245 0586

1 pound-Centigrade heat unit per minute [lb-C/min]:

=	31.646 9 watts. Aprx. 32.....	1.500 3311
=	0.043 030 8 metric horse-power. Aprx. $\frac{3}{4} \div 10$	2.633 7794
=	0.042 442 1 horse-power. Aprx. $\frac{3}{4} \div 10$	2.627 7964
=	0.031 646 9 kilowatt. Aprx. $32 \div 1\ 000$	2.500 3311

1 watt-hour per minute=60. watts..... 1.778 1513

1 calorie (large) per minute [Cal/min]:

=	69.769 5 watts. Aprx. 70.....	1.843 6653
=	0.094 866 7 metric horse-power. Aprx. $\frac{3}{21}$	2.977 1136
=	0.093 568 7 horse-power. Aprx. $\frac{3}{32}$	2.971 1306
=	0.069 769 5 kilowatt. Aprx. $\frac{7}{100}$	2.843 6653

1 mile-pound per minute [ml-lb/min]:

=	119.304 watts. Aprx. 120.....	2.076 6548
=	0.162 220 metric horse-power. Aprx. $\frac{8}{5} \div 10$	1.210 1031
=	0.160 000 horse-power. Aprx. $\frac{8}{5} \div 10$	1.204 1200
=	0.119 304 kilowatt. Aprx. $\frac{6}{5} \div 10$	1.076 6548

1 kilogram-kilometer per minute [kg-km/min]:

=	163.433 watts. Aprx. $\frac{1}{6} \times 1\ 000$	2.213 3391
=	0.222 222 metric horse-power. Aprx. $\frac{2}{9}$	1.346 7875
=	0.219 182 horse-power. Aprx. $\frac{2}{9}$	1.340 8044
=	0.163 433 kilowatt. Aprx. $\frac{1}{6}$	1.213 3391

1 metric horse-power [hp] or French horse-power or chevalvapeur or force de cheval or Pferde-kraft:

=	7.354 48 $\times 10^9$ ergs per second. Aprx. $2\frac{2}{3} \times 10^9$	9.866 5517
=	32 548.5 foot-pounds per minute. Aprx. 33 000.....	4.512 5309
=	4 500. kilogram-meters per minute. Aprx. $\frac{9}{2} \times 1000$	3.653 2125
=	735.448 watts. Aprx. $2\frac{2}{3} \times 100$	2.866 5517
=	542.475 foot-pounds per second. Aprx. $\frac{9}{11} \times 1\ 000$..	2.734 3797
=	75. kilogram-meters per second or $\frac{3}{4} \times 100$	1.875 0613
=	41.830 5 thermal units per minute. Aprx. 42.....	1.621 4931
=	23.239 2 lb-Ctg. heat units per minute. Aprx. $\frac{7}{3} \times 10$..	1.366 2206
=	10.541 1 large calories per minute. Aprx. $2\frac{1}{2}$	1.022 8864
=	0.986 318 horse-power. Aprx. 1.....	1.994 0170
=	0.750 000 poncelet.....	1.875 0613
=	0.735 448 kilowatt. Aprx. $2\frac{2}{3} \div 10$	1.866 5517

1 horse-power [hp]:

=	7.456 50 $\times 10^9$ ergs per second. Aprx. $\frac{3}{4} \times 10^{10}$	9.872 5348
=	33 000. foot-pounds per min. Aprx. $\frac{1}{2} \times 100\ 000$...	4.518 5139
=	4 562.42 kg-meters per minute. Aprx. $\frac{9}{2} \times 1\ 000$	3.659 1956
=	745.650 watts. Aprx. $\frac{3}{4} \times 1\ 000$	2.872 5348
=	550. foot-pounds per second. Aprx. $1\frac{1}{2} \times 100$...	2.740 3627
=	375.000 mile-pounds per hour. Aprx. $\frac{3}{8} \times 1\ 000$	2.574 0313
=	76.040 4 kg-meters per second. Aprx. $\frac{3}{4} \times 100$	1.881 0444
=	42.410 8 thermal units per min. Aprx. $\frac{3}{4} \times 100$	1.627 4762
=	23.561 5 lb-Ctg. heat units per min. Aprx. $\frac{7}{3} \times 10$..	1.372 2037
=	10.687 3 large calories per min. Aprx. $\frac{3}{2}\frac{1}{2}$	1.028 8695
=	1.013 87 metric horse-powers. Aprx. 1.....	0.005 9830
=	0.760 404 poncelet. Aprx. $\frac{3}{4}$	1.881 0444
=	0.745 650 kilowatt. Aprx. $\frac{3}{4}$	1.872 5348

1 poncelet=	100. kilogram-meters per second.....	2.000 0000
"	= 1.333 33 metric horse-powers. Aprx. $\frac{4}{3}$	0.124 9387
"	= 1.315 09 horse-powers. Aprx. $\frac{4}{3}$	0.118 9557
"	=0.980 597 kilowatt. Aprx. 1.....	1.991 4904
1 kilowatt [kw]=	1×10^{10} ergs per second.....	10.000 0000
"	=44 256.7 ft-lbs per min. Aprx. $\frac{4}{3} \times 100\ 000$..	4.845 9793
"	=6 118.72 kg-met. per min. Aprx. $6 \times 1\ 000$..	3.786 6609
"	= 1 000. watts.....	3.000 0000
"	= 737.612 ft-lbs. per sec. Aprx. $\frac{3}{4} \times 1\ 000$	2.867 8279
"	= 101.979 kilogram-metr. per sec. Aprx. 100.	2.008 5096
"	=56.877 6 thermal u. per min. Aprx. $\frac{4}{3} \times 100$.	1.754 9414
"	=31.598 7 lb-Ctg. heat u. per min. Aprx. $\frac{63}{2}$..	1.499 6889
"	=14.332 9 large cal. per min. Aprx. $\frac{1}{3} \times 100$..	1.156 3347
"	=1.359 72 metric horse-powers. Aprx. add $\frac{1}{3}$.	0.133 4483
"	=1.341 11 horse-powers. Aprx. add $\frac{1}{3}$	0.127 4652
"	=1.019 79 poncelets. Aprx. 1.....	0.008 5096
1 watt-hour per second	=3 600. watts. Aprx. $\frac{1}{3} \times 1\ 000$...	3.556 3025
"	=3.600 kilowatts. Aprx. $\frac{1}{3}$	0.556 3025
1 metric horse-power-hour per minute:		
=60. metric horse-powers.....		1.778 1513
1 horse-power-hour per minute=60. horse-powers		1.778 1513
1 kilowatt-hour per minute= 60. kilowatts.....		1.778 1513
1 metric horse-power-hour per second:		
=3 600. metric horse-powers. Aprx. $\frac{1}{3} \times 1\ 000$		3.556 3025
1 horse-power-hour per second:		
=3 600. horse-powers. Aprx. $\frac{1}{3} \times 1\ 000$		3.556 3025
1 kilowatt hour per second:		
=3 600. kilowatts. Aprx. $\frac{1}{3} \times 1\ 000$		3.556 3025

Conversion Tables for Power.

Horse-powers =	kilowatts.				metr hp's	
Metric hp's =	.....		kilowatts .....		.....	horse-
Kilowatts =	.....	horse-	.....	metr hp's	.....	powers
		powers				
1	0.745 65	1.341 1	0.735 45	1.359 7	1.013 9	0.986 32
2	1.491 3	2.682 2	1.470 9	2.719 4	2.027 7	1.972 6
3	2.237 0	4.023 3	2.206 3	4.079 2	3.041 6	2.959 0
4	2.982 6	5.364 4	2.941 8	5.438 9	4.055 5	3.945 3
5	3.728 3	6.705 6	3.677 2	6.798 6	5.069 4	4.931 6
6	4.473 9	8.046 7	4.412 7	8.158 3	6.083 2	5.917 9
7	5.219 6	9.387 8	5.148 1	9.518 0	7.097 1	6.904 2
8	5.965 2	10.729	5.883 6	10.878	8.111 0	7.890 5
9	6.710 9	12.070	6.619 0	12.237	9.124 8	8.876 9
10	7.456 5	13.411	7.354 5	13.597	10.139	9.863 2

FORCES; WEIGHTS Considered as Forces. (See also Weights.)*

Only true units of force (dynes and poundals) are given here, together with their values in terms of weights, and the reciprocals of these values. The relations between two weights when considered as forces are, of course, the same as when they are considered as masses; these have been given under Weights and are therefore not repeated here.

A true unit of force is independent of the value of gravity and is the same throughout the universe. But a weight considered as a force includes the value of gravity and is therefore different for different values of gravity. The value of gravity used in these tables is 980.596 6 (see note on this value under the units of Acceleration).

A dyne is that force which, acting on a mass of one gram for one second, produces a velocity of one centimeter per second; this definition refers to a space which is free from the attraction of other bodies. A poundal is similarly that force which, acting on a mass of one pound for one second, produces a velocity of one foot per second.

The attraction of gravity of the earth is really a force, but it cannot be used as a unit of force, as the amount of this force which acts on any body depends on the mass on which it acts. When reduced to the force per gram mass, it becomes the same thing as the force represented by one gram considered as a weight, and this together with all similar values is given in the table. The attraction of gravitation becomes a constant quantity when it is stated as an acceleration, as in this form it is independent of the mass on which it acts; it can then be used as a unit and is included as such in the table of accelerations, which see for its reduction factors.

For tractive forces or tractive efforts, see under this title at the end of units of Energy.

Aprx. means within 2%.

	Logarithm
1 microdyne = 0.000 001 dyne.....	6.000 0000
1 milligram = 0.980 596 6 dyne. Aprx. 98 ÷ 100	1.991 4904
" = 0.000 070 926 5 poundals. Aprx. 7 ÷ 100 000...	5.850 8088
1 dyne = 1.019 79 milligrams. Aprx. 1.	0.008 5096
" = 0.015 737 7 grain. Aprx. $1\frac{1}{4}$ ÷ 100.	2.196 9418
" = 0.001 019 79 gram. Aprx. 1 ÷ 1 000.	3.008 5096
" = 0.000 035 971 9 ounce (av.). Aprx. 4 ÷ 110 000.	5.555 9637
" = 0.000 072 330 0 poundal. Aprx. $\frac{5}{4}$ ÷ 10 000.	5.859 3184
" = 0.000 002 248 25 pound (av.). Aprx. $\frac{1}{4}$ ÷ 1 000 000.	6.351 8437
1 grain = 63.541 6 dynes. Aprx. $\frac{7}{11}$ × 100.	1.803 0582
" = 0.001 595 96 poundal. Aprx. 46 ÷ 10 000.	3.662 3766
1 gram = 980.596 6 dynes. Aprx. 1 000.	2.991 4904
" = 0.070 926 5 poundal. Aprx. 7 ÷ 100.	2.850 8088
1 kilodyne = 1 000. dynes.	3.000 0000
1 myriadyne = 10 000. dynes.	4.000 0000
1 poundal = 14 099.1 milligrams. Aprx. $\frac{1}{4}$ × 100 000.	4.149 1912
" = 13 825.5 dynes. Aprx. $1\frac{1}{8}$ × 10 000.	4.140 6816
" = 217.582 grains. Aprx. 220.	2.337 6234
" = 14.099 1 grams. Aprx. $\frac{1}{4}$ × 100.	1.149 1912
" = 0.497 331 ounce (av.). Aprx. $\frac{1}{2}$	1.696 6453
" = 0.031 083 2 pound. Aprx. 31 ÷ 1 000.	2.492 5253
" = 0.014 099 1 kilogram. Aprx. $\frac{1}{70}$	2.149 1912
1 ounce (av.) = 27 799.5 dynes. Aprx. $1\frac{1}{4}$ × 10 000.	4.444 0363
" = 2.010 73 poundals. Aprx. 2.	0.303 3547
1 pound (av.) = 444 791. dynes. Aprx. $\frac{1}{4}$ × 1 000 000.	5.648 1563
" = 32.171 7 poundals. Aprx. 32.	1.507 4746
1 kilogram = 980 596.6 dynes. Aprx. 1 000 000.	5.991 4904
" = 70.926 5 poundals. Aprx. 70.	1.850 8088
" = 0.980 597 megadyne. Aprx. 1.	1.991 4904
1 megadyne = 1 000 000. dynes.	6.000 0000
" = 72.330 0 poundals. Aprx. $\frac{5}{4}$ × 100.	1.859 3184
" = 2.248 25 pounds. Aprx. $\frac{1}{4}$	0.351 8437
" = 1.019 79 kilograms. Aprx. 1.	0.008 5096

1 pound per ton }
1 kilogram per ton } see under Tractive Forces, p. 78.

MOMENTS of INERTIA. (Mass $\times$ square of length.)

The moment of inertia of a body is its mass multiplied by the square of the radius of gyration; it must therefore always refer to some axis of rotation. It represents that weight which when concentrated at a unit distance from the axis of rotation would require the same energy to cause a given increase in its angular velocity, that the body itself requires. It bears the same relation to angular acceleration as weight bears to linear acceleration.

Moments of inertia (so-called) are frequently used in calculating the strength of beams of various cross-sections. In such cases the formulas usually represent the moments of inertia of each of differently shaped cross-sections, and the mass is then usually represented by its cross-sectional area, as the formulas are then the same for all materials provided only that the shape of the cross-section is the same; the numbers thus obtained are often (though not correctly) called the moments of inertia; they might better be called the specific moment of inertia of the respective cross-section. The figure obtained from such a formula must then be multiplied by the mass (weight) of a cube (of unit side) of the material to give the true moment of inertia, if that is required, of a slab or section having a thickness of one unit of length. In calculations involving the ratio of two different moments of inertia, the weight or mass need not be introduced provided the material is the same in both; in all such cases the figures obtained from the formulas just mentioned can be used directly. In such cases the relation between the units in which the moments of inertia are expressed is as the fourth power of the respective linear units.

MOMENTS of INERTIA in terms of the mass.

	Logarithm
1 unit in pounds and inches:	
= 2.926 41 units in kilograms and centimeters.....	0.466 3350
1 unit in kilograms and centimeters:	
= 0.341 716 unit in pounds and inches..	1.533 6650

MOMENTS of INERTIA in terms of the surface.

1 unit in inches = 41.623 5 units in centimeters.	1.619 3384
1 unit in centimeters = 0.024 024 9 unit in inches.....	2.380 0616

Thus if the moment of inertia (so-called) of the cross-section of a beam, for instance, has been calculated in inches and square inches and is then multiplied by 41.62, the result would be the same as if the moment of inertia of the same cross-section had been calculated in centimeters and square centimeters.

MOMENTS of MOMENTUM; ANGULAR MOMENTUM.

(Momentum $\times$ length.)

These units are simply those of momentum multiplied by a length, and as they are seldom used it is not necessary to give them in a separate table. The units of momentum are given above (see under Power); the length by which they are to be multiplied must of course be in terms of the same unit as the one already included in the respective unit of momentum. The moment of momentum is also equal to the moment of inertia divided by time.

LINEAR VELOCITIES; SPEEDS. (Length ÷ time.)

For simple reductions or relations between lengths, see units of Length.
 Aprx. means within 2%.

Logarithm

1 foot per minute [ft/min]:

= 0.304 801 meter per minute. Aprx. $\frac{3}{10}$	1.484 0158
= 0.018 288 0 kilometer per hour. Aprx. $\frac{2}{11} \div 10$	2.262 1671
= 0.016 666 7 foot per second. Aprx. $\frac{1}{6} \div 10$	2.221 8487
= 0.011 363 6 mile per hour. Aprx. $\frac{8}{7} \div 100$	2.055 5174

1 kine = 1 centimeter per second..... 0.000 0000

1 centimeter per second [cm/s]:

= 1 kine.....	0.000 0000
= 0.01 meter per second, which see for other values.....	2.000 0000

1 meter per minute [m/min]:

= 3.280 83 feet per minute. Aprx. $\frac{1}{3}$	0.515 9842
= 0.06 kilometer per hour.....	2.778 1513
= 0.054 680 6 foot per second. Aprx. $\frac{1}{2} \div 100$	2.737 8329
= 0.037 282 2 mile per hour. Aprx. $\frac{3}{8} \div 10$	2.571 5016

1 kilometer per hour [km/hr]:

= 54.680 6 feet per minute. Aprx. $\frac{1}{2} \times 10$	1.737 8329
= 16.666 7 meters per minute. Aprx. $\frac{1}{6} \times 100$	1.221 8487
= 0.911 343 foot per second. Aprx. $\frac{1}{11}$	1.959 6816
= 0.621 370 mile per hour. Aprx. $\frac{5}{8}$	1.793 3503
= 0.539 611 knot (Brit.) per hour. Aprx. $\frac{6}{11}$	1.732 0806
= 0.539 593 knot (U. S.) per hour. Aprx. $\frac{6}{11}$	1.732 0660

1 foot per second [ft/s]:

= 60. feet per minute.....	1.778 1513
= 18.288 0 meters per minute. Aprx. $\frac{1}{6} \times 10$	1.262 1671
= 1.097 28 kilometers per hour. Aprx. add $\frac{1}{10}$	0.040 3184
= 0.681 818 mile per hour. Aprx. $68 \div 100$	1.833 6687
= 0.592 105 knot (Brit.) per hour. Aprx. $\frac{6}{10}$	1.772 3990
= 0.592 085 knot (U. S.) per hour. Aprx. $\frac{6}{10}$	1.772 3844
= 0.304 801 meter per second. Aprx. $\frac{3}{10}$	1.484 0158
= 0.018 288 0 kilometer per minute. Aprx. $\frac{1}{6} \div 100$	2.262 1671
= 0.011 363 6 mile per minute. Aprx. $\frac{8}{7} \div 100$	2.055 5174

1 mile per hour [mi/hr]:

= 88. feet per minute.....	1.944 4827
= 26.822 4 meters per minute. Aprx. $\frac{8}{3} \times 10$	1.428 4984
= 1.609 35 kilometers per hour. Aprx. $\frac{8}{5}$	0.206 6497
= 1.466 67 feet per second. Aprx. $\frac{1}{3}$	0.186 3313
= 0.868 421 knot (Brit.) per hour. Aprx. $\frac{7}{8}$	1.938 7303
= 0.868 392 knot (U. S.) per hour. Aprx. $\frac{7}{8}$	1.938 7157
= 0.447 041 meter per second. Aprx. $\frac{9}{2} \div 10$	1.650 3471
= 0.026 822 4 kilometer per minute. Aprx. $\frac{8}{3} \div 100$	2.428 4984
= 0.016 666 7 mile per minute. Aprx. $\frac{1}{6} \div 10$	2.221 8487

1 knot (Brit.) per hour:

= 1.853 19 kilometers per hour. Aprx. $\frac{1}{6}$	0.267 9194
= 1.688 89 feet per second. Aprx. $\frac{1}{6}$	0.227 6011
= 1.151 52 miles per hour. Aprx. add $\frac{1}{7}$	0.061 2897
= 0.999 966 knot (U. S.) per hour. Aprx. 1.....	1.999 9354

1 knot (U. S.) per hour:

= 1.853 25 kilometers per hour. Aprx. $\frac{1}{6}$	0.267 9340
= 1.688 94 feet per second. Aprx. $\frac{1}{6}$	0.227 6157
= 1.151 55 miles per hour. Aprx. add $\frac{1}{7}$	0.061 2843
= 1.000 034 knots (Brit.) per hour. Aprx. 1.....	0.000 0146

1 meter per second [m/s]:

= 196.850 feet per minute. Aprx. 200.....	2.294 1355
= 100. centimeters per second.....	2.000 0000
= 60. meters per minute.....	1.778 1513
= 3.6 kilometers per hour.....	0.556 3025
= 3.280 83 feet per second. Aprx. $\frac{1}{3}$	0.515 9842
= 2.236 93 miles per hour. Aprx. $\frac{9}{4}$	0.349 6529
= 0.06 kilometer per minute.....	2.778 1513
= 0.037 282 2 mile per minute. Aprx. $\frac{1}{27}$	2.571 5016

1 kilometer per minute [km/min]:

= 54.680 6 feet per second. Aprx. 55.....	1.737 8329
= 37.282 2 miles per hour. Aprx. 37.....	1.571 5016
= 16.666 7 meters per second. Aprx. $\frac{1}{6} \times 100$	1.221 8487
= 0.621 370 mile per minute. Aprx. $\frac{5}{8}$	1.793 3503

1 mile per minute [ml/min]:

= 88. feet per second.....	1.944 4827
= 60. miles per hour.....	1.778 1513
= 26.822 4 meters per second. Aprx. 27.....	1.428 4984
= 1.609 35 kilometers per minute. Aprx. $\frac{8}{9}$	0.206 6497

Miscellaneous concrete units: Average velocity of molecules about 500. meters per second (Woodward). Velocity of light about 300 000. kilometers per second.

ANGULAR VELOCITIES; ROTARY SPEEDS.(Angle $\div$ time.)

For simple reductions or relations between angles, see values under Angles. Aprx. means within 2%.

Angular velocity = angle moved through divided by time.

"	"	in degrees per second = angle in degrees $\div$ time in seconds.
"	"	= revolutions per second $\times 360$.
"	"	in revolutions per minute = revolutions $\div$ time in minutes.
"	"	in radians per second = $2\pi \times$ revolutions per second.

Logarithm

1 revolution per hour [rev/h or rph]:

= 0.1 degree per second.....	1.000 0000
------------------------------	------------

1 radian per minute:

= 9.549 30 revolutions per hour. Aprx. $1\frac{1}{2}$	0.979 9714
= 0.954 930 degree per second. Aprx. subtract $\frac{1}{20}$	1.979 9714
= 0.002 652 58 revolution per second. Aprx. $\frac{8}{3} \div 1\ 000$	3.423 6689

1 degree per second:

= 10. revolutions per hour.....	1 000 0000
= 1.047 20 radians per minute. Aprx. add $\frac{1}{20}$..	0.020 0287
= 0.166 667 revolution per minute or $\frac{1}{6}$	1.221 8487
= $\frac{1}{360}$ or 0.002 777 78 rev per second. Aprx. $\frac{3}{11} \div 100$	3.443 6975

1 revolution per minute [rev/min or rpm]:

= 6. degrees per second.....	0.778 1513
= 0.104 720 radian per second. Aprx. $2\frac{1}{2} \div 100$	1.020 0287
= 0.016 666 7 rev per second or $\frac{1}{60}$	2.221 8487

1 radian per second [ω]:

= 57 295 8 degrees per second. Aprx. 57.....	1.758 1226
= 0.159 155 revolutions per second Aprx. $1\frac{1}{4} \div 100$	1.201 8201

(revolution per second [rev/s or rps]:

= 60. revolutions per minute.....	1.778 1513
= 6.283 185 radians per second. Aprx. $\frac{5}{8} \times 10$	0.798 1799

FREQUENCY; PERIODICITY; PERIOD; ALTERNATIONS. (1 $\div$ time; time.)

Frequency or periodicity is the number of recurrences of some periodic or wave motion during a given time; this time is always understood to be a second unless otherwise stated; the frequency always refers to the number of *complete* waves. The "number of alternations" however, refers to the number of changes of the direction of the motion or to the reversals, and therefore refers to half waves, and is always equal to double the frequency, if the time is the same. The period is the time of one complete wave or oscillation and is therefore the reciprocal of the frequency. The term frequency is the one most generally used, and always refers to a second; the term number of alternations is unfortunately preferred by some and when it refers to electric currents the time is usually a minute; the term period is used comparatively rarely as a measure, its use being generally limited to scientific discussions.

In mathematical discussions of electric alternating-current problems the frequency is often replaced by an angular velocity, generally represented by ω and measured in radians per second (see under Angular Velocities above). Then $\omega = 2\pi n$, in which ω is in radians per second and n is the true frequency in cycles per second, a cycle being here considered the same thing as a complete revolution.

The frequency is also equal to the velocity of propagation divided by the wave length. The wave lengths are therefore measured in units of length, but when the velocity for a class of waves is a constant (as those of light or the electromagnetic waves), the wave lengths may also be indicated in units of time, in which case a wave length becomes equal to the period of the wave. Wave length should not be confounded with the amplitude, which latter measures the intensity of the wave and has nothing to do with the frequency, period, or wave length.

If n is the **frequency** per second [ω], then:

the period in seconds $= 1/n$;

the number of alternations per minute $= 120n$.

If n is the **number of alternations** per minute, then:

the frequency per second $= n/120$;

the period in seconds $= 120/n$.

If n is the **period** in seconds, then:

the frequency per second $= 1/n$;

the number of alternations per minute $= 120n$.

If n is the **frequency** in cycles per second, ω the **angular velocity** in radians per second, and if a cycle is represented by one revolution, then:

$\omega = 2\pi n$; or

$n = 0.159\ 155\ \omega$;

$\omega = 6.283\ 19\ n$

An **electrical degree** is the 360th part of one complete cycle.

LINEAR ACCELERATIONS; RATE of INCREASE in VELOCITIES; GRAVITY. (Velocity $\div$ time.)

The mean value for "gravity" which has been taken as a basis in all these tables is an acceleration of 9.805 966 meters per second per second, at sea-level and in latitude 45° . This is probably the best available mean value and is known as Helmert's value (*Die math. u. phys. Theorien der hoehern Geodaesie*; II, p. 241; 1884). It is used up to date by the International Geodetic Association, according to its latest published report. No value has been adopted by the National Bureau of Standards. At the International Bureau of Weights and Measures the value 9.809 91 is taken, from which the normal value at sea-level and in latitude 45° would be 9.806 65; the difference is only about 7 in one hundred thousand.

This value enters into many figures involving relations between forces and masses, as, for instance, in the relation between watts and horse-power, because a watt is defined in terms of a dyne (that is, a true force, which is independent of gravity), while a horse-power is defined in terms of pounds or kilograms (that is, masses which must be multiplied by the value of gravity to be reduced to true forces comparable with dynes). The value of gravity, however, falls out in all figures involving the relation between two masses when *both* are considered as forces, as, for instance, in the relation between foot-pounds and kilogram-meters, which involve pounds and kilograms considered as forces. It does not enter at all in the inter-relations between watts, joules, ergs, and dynes, as these are the same throughout the universe. Pounds, kilograms, etc., are really masses, and as such are the same throughout the universe, but when considered as weights or forces their values depend on gravity and are slightly different on different parts of the earth; when measured on a beam balance by comparison with other weights, their values would remain the same, but when measured on a spring balance their values would change slightly, as the spring measures the force of gravity acting on the masses.

The "gravity" here referred to, which is an acceleration and pertains only to our earth, should not be confounded with what is called the "gravitation constant" or "Newton's constant," which pertains to the whole universe, and is the constant by which one must multiply the product of

the masses of two bodies divided by the square of their distance apart, in order to get the force of attraction between them.

Aprx. means within 2%.

	Logarithm
1 kilometer per hour per min. [km/hr/min] (or per min. per hour):	
= 0.016 666 7 or $\frac{1}{60}$ kilometer per hour per second (or per second per hour) which see for other values.	2.221 8487
1 mile per hour per minute [ml/hr/min] (or per minute per hour):	
= 0.016 666 7 or $\frac{1}{60}$ mile per hour per second (or per sec. per hr.), which see for other values.	2.221 8487
1 centimeter per second per second [cm/s²]:	
= 0.036 kilometer per hour per second (or per second per hour).	2.556 3025
= 0.032 808 3 foot per second per second. Aprx. $\frac{1}{3} \div 10$.	2.515 9842
= 0.022 369 3 mile per hour per second (or per second per hour). Aprx. $\frac{1}{4} \div 100$.	2.349 6529
= 0.001 019 79 gravity. Aprx. $\frac{1}{1000}$.	3.008 5096
1 kilometer per hour per second [km/hr/s] or per second per hour):	
= 27.777 8 centimeters per second per second. Aprx. 28	1.443 6975
= 0.911 343 foot per second per second. Aprx. subtr. $\frac{1}{11}$.	1.959 6816
= 0.621 370 mile per hour per second (or per second per hour). Aprx. $\frac{5}{8}$.	1.793 3503
= 0.277 778 meter per second per second. Aprx. $\frac{3}{11}$.	1.443 6975
= 0.028 327 4 gravity. Aprx. $\frac{3}{4} \div 10$.	2.452 2071
1 foot per second per second [ft/s²]:	
= 30.480 1 centimeters per second per second. Aprx. 30.	1.484 0158
= 1.097 28 kilometers per hour per second (or per second per hour). Aprx. add $\frac{1}{10}$.	0.040 3184
= 0.681 818 mile per hour per second (or per second per hour). Aprx. $\frac{4}{60}$.	1.833 6687
= 0.304 801 meter per second per second. Aprx. $\frac{3}{10}$.	1.484 0158
= 0.031 083 2 gravity. Aprx. $31 \div 1000$.	2.492 5254
1 mile per hour per second [ml/hr/sec] or per second per hour:	
= 44.704 1 centimeters per sec per sec. Aprx. $\frac{9}{2} \times 10$.	1.650 3471
= 1.609 35 kilometers per hour per second (or per second per hour). Aprx. $\frac{9}{5}$.	0.206 6497
= 1.466 67 feet per second per second. Aprx. $\frac{44}{30}$.	0.166 3313
= 0.447 041 meter per second per second. Aprx. $\frac{9}{2} \div 10$.	1.650 3471
= 0.045 588 6 gravity. Aprx. $\frac{9}{2} \div 100$.	2.658 8567
1 meter per second per second [m/sec²]:	
= 3.6 kilometers per hr. per sec. (or per sec. per hr.)..	0.556 3025
= 3.280 83 feet per second per second. Aprx. $\frac{1}{3} \times 10$.	0.515 9842
= 2.236 93 miles per hr per sec (or per s per hr). Aprx. $\frac{9}{4}$.	0.349 6529
= 0.101 979 gravity. Aprx. $\frac{1}{10}$.	1.008 5096
Gravity = 980.596 6 centimeters per sec per sec. Aprx. 1 000..	2.991 4904
" = 35.301 5 kilometers per hour per second (or per second per hour). Aprx. $\frac{7}{2} \times 10$.	1.547 7929
" = 32.171 7 feet per second per second. Aprx. 32.	1.507 4748
" = 21.935 3 miles per hr per sec (or /sec/hr). Aprx. 22	1.341 1433
" = 9.805 966 meters per second per second. Aprx. 10.	0.991 4904

ANGULAR ACCELERATIONS; RATE of INCREASE in ANGULAR VELOCITIES. (Angular velocity $\div$ time.)

	Logarithm
1 revolution per minute per minute [rev/min/min]:	
= 0.016 666 7 or $\frac{1}{60}$ rev per min per sec (or per s per m)..	2.221 8487
= 0.000 277 778 or $\frac{1}{3600}$ rev per s per s. Aprx. $\frac{3}{11} \div 1000$.	4.443 6975
1 revolution per minute per second [rev/min/s] or per second per minute:	
= 60. revolutions per minute per minute	1.778 1513
= 0.016 666 7 or $\frac{1}{60}$ revolution per second per second.	2.221 8487
1 revolution per second per second [rev/s/s]:	
= 3 600. revolutions per minute per minute.	3.556 3025
= 60. rev per minute per second (or per sec per min.)...	1.778 1513

ANGLES (plane); CIRCULAR MEASURE.

Aprx. means within 2%.	Logarithm
1 second ["]=0.016 666 7 minute, or $\frac{1}{60}$	2.221 8487
1 minute ["]=50. seconds.....	1.778 1513
"=0.016 666 7 degree, or $\frac{1}{60}$	2.221 8487
"=0.000 290 888 radian.....	4.463 7261
"=0.000 185 185 quadrant.....	4.267 6062
"=0.000 046 296 3 circumference.....	5.665 5462
1 grade=0.01 right angle.....	2.000 0000
1 degree [°]:	
=3 600. seconds.....	3.556 3025
=60. minutes.....	1.778 1513
=0.017 453 3 radian. Aprx. $\frac{74}{100}$	2.241 8774
=0.011 111 1 quadrant, or $\frac{1}{40}$	2.045 7575
=0.005 555 56 π 's (considered as an angle of 180°), or $\frac{1}{180}$..	3.744 7275
=0.002 777 78 circumference, or $\frac{1}{360}$	3.443 6975
1 radian:	
=angle whose arc equals radius.	
=206 265. seconds.....	5.314 4252
=3 437.75 minutes. Aprx. 3400.....	3.536 2739
=57.295 8 degrees. Aprx. 57.....	1.758 1226
=0.636 620 quadrant. Aprx. $\frac{71}{100}$	1.803 8801
=0.318 310 π 's (considered as an angle of 180°). Ap. $\frac{32}{100}$..	1.502 8501
=0.159 155 circumference. Aprx. $\frac{10}{100}$	1.201 8201
1 quadrant or right angle:	
=100. grades.....	2.000 0000
=90. degrees.....	1.954 2425
=1.570 80 radians. Aprx. $\frac{11}{100}$	0.196 1199
=0.5 π 's (considered as an angle of 180°), or $\frac{1}{2}$	1.698 9700
=0.25 circumference, or $\frac{1}{4}$	1.397 9400
π (as an angle) or semi-circumference:	
=180. degrees.....	2.255 2725
=3.141 59 radians. Aprx. $\frac{22}{7}$	0.497 1499
=2. quadrants.....	0.301 0300
=0.5 circumference, or $\frac{1}{2}$	1.698 9700
1 circumference or revolution [rev]	
=21 600. minutes.....	4.334 4538
=360. degrees.....	2.556 3025
=6.283 185 radians. Aprx. $\frac{5}{8} \times 10$	0.798 1799
=4. quadrants.....	0.602 0600
=2. π 's (considered as an angle of 180°).....	0.301 0300
1 electrical degree=the 360th part of a cycle; see p. 121.	

SOLID ANGLES. (Surface $\div$ radius.)

A solid angle is an angle, like that at the point of a cone, which is subtended by a spherical surface. The unit solid angle is that angle which, at the center of a sphere of unit radius, subtends a unit area on the surface of the sphere; this unit is sometimes called a steradian. A spherical right angle is assumed to be an angle, like at the corner of a rectangular block, which is bounded by three planes perpendicular to each other.

	Logarithm
1 unit=0.636 620 spherical right angle, or $2/\pi$	1.803 8801
"=0.159 155 hemisphere, or $1 \div 2\pi$	1.201 8201
"=0.079 577 5 sphere, or $1 \div 4\pi$	2.900 7901
1 steradian=1 unit solid angle; (see above).....	0.000 0000
1 spherical right angle=1.570 80 units, or $\pi/2$	0.196 1199
"=0.25 hemisphere, or $\frac{1}{4}$	1.397 9400
"=0.125 sphere, or $\frac{1}{8}$	1.096 9100
1 hemisphere=6.283 19 units, or 2π	0.798 1799
"=4. spherical right angles.....	0.602 0600
"=0.5 sphere, or $\frac{1}{2}$	1.698 9700
1 sphere=12.566 4 units, or 4π	1.099 2099
"=8. spherical right angles.....	0.903 0900
"=2. hemispheres.....	0.301 0300

GRADES; SLOPES; INCLINES. (Angle; $\text{length} \div \text{length.}$)

Grades are indicated in terms of so many different kinds of units, some of which involve trigonometric relations, that the relations between some of them become complicated. Those given in the following table are mathematically correct and are strictly proportional; they may therefore be used like those in the other tables; for instance, a 1% grade from the table is 52.8 feet rise per mile, hence a 5% grade will be 5 times this; or from the table, 1 foot per mile is a 0.0189% grade, hence 100 feet per mile will be a 1.89% grade.

Much unnecessary labor and confusion would be avoided if grades were uniformly represented in percent, that is, in the rise per hundred. There seems to be a tendency to adopt this unit generally. In the following table all the relations are given in terms of the percent unit as a basis; the relation between any two others is readily found by reducing both to the same percentage value.

In using **percentage** values it should be remembered that they mean the rise **per hundred**, and it may therefore be necessary sometimes to multiply or divide by 100 when the actual or total distances or rises are involved. Thus a rise of 12 feet in 600 feet is a 2% grade, as the 600 feet must first be **divided by 100** to reduce it to hundreds, before dividing it into 12. Or if the total rise on a 2% grade is given as 12 feet, it means $12 \div 2 = 6$ feet **per hundred**, which must therefore be multiplied by 100 to get the total distance.

Much confusion arises from the incorrect way in which percentage values are not infrequently written. Thus fifty percent should be written 50% and not .50%, which latter means half of one percent, or fifty hundredths of one percent.

Much confusion also arises from the fact that sometimes the sloping or inclined distance is meant instead of the horizontal distance, and generally it is not stated which one is understood. In referring to profiles or to distances on a map, the horizontal distance is always understood, thus involving the tangent of the angle; while in formulas for the traction on grades, or when the distances are the actual lengths of track or road, the sloping or inclined distance is generally implied, as the traction formulas then become simpler; they then involve the sine of the angle. The present table gives the correct reduction factors for both. Some of these are the same in both systems; but it should be understood that a grade of a given percent based on horizontal distances is slightly different from a grade of the same percent based on sloping distances; the latter is always the larger angle or steeper grade. The difference is however generally negligibly small for all but exceptionally steep grades; up to a 14% grade, which is about the limit for traction on rails and for the usual roads, the difference is less than 1%.

The following reduction factors are the same whether the units are based on the **horizontal** or on the **sloping** distances.

		Logarithm
1 inch per mile [in/ml]	= 0.001 578 28%	3.198 1849
1 foot per mile [ft/ml]	= 0.018 939 4%	2.277 3661
1 %	= 0.1%	1.000 0000
1 per mil [‰]	= 0.1%	1.000 0000
1 millimeter per meter [mm/m]	= 0.1%	1.000 0000
1 foot per thousand feet [ft/M]	= 0.1%	1.000 0000
1 foot per 100 feet [ft/C]	= 1%	0.000 0000
1 foot rise per foot [ft/ft]	= 100%	2.000 0000
1% = 633.6 inches per mile		2.801 8152
" = 52.8 feet per mile		1.722 6339
" = 10. ‰, or 10 per mil		1.000 0000
" = 10. millimeters per meter		1.000 0000
" = 10. feet per thousand feet		1.000 0000
" = 1. foot per hundred feet		0.000 0000
" = 0.01 foot rise per foot		2.000 0000

n miles per foot rise $= 1/n$ feet rise per mile.
 $= (0.018\ 939\ 4 \div n)\%$.
 $n\%$ $= (0.018\ 939\ 4 \div n)$ miles per foot rise.
 n feet (rise) per mile $= 1/n$ miles per foot rise.

n feet per foot rise $= 1/n$ feet (rise) per foot.
 $= (100/n)\%$.
 $n\%$ $= (100/n)$ feet per foot rise.
 n foot (rise) per foot $= 1/n$ foot per foot rise.

The following reduction factors are only for units based on the **horizontal** distances.

$n\%$ $= \frac{100n}{\sqrt{100^2 + n^2}}\%$ based on sloping distances.

$n\%$ $= 100 \times \sin.$

n degrees rise $= (100 \tan n)\%$.

$n\%$ $=$ number of degrees whose tangent is $0.01n$.

If n is the **tangent of angle**, then the **rise in $\%$** $= 100n$.

If n is the **rise in $\%$** , then the **$\tan$** $= 0.01n$.

If n is the **sine of angle**, then the **rise in $\%$** $= \frac{100n}{\sqrt{1 - n^2}}$. Or find from a table the tangent corresponding to this sine, then the **rise in $\%$** $= 100 \times \tan$.

If n is the **rise in $\%$** , then the **sine of the angle** $= \frac{n}{\sqrt{100^2 + n^2}}$. Or the sine may be found from a table as that corresponding to $\tan = 0.01n$.

The following reduction factors are only for units based on the **sloping** distances.

$n\%$ $= \frac{100n}{\sqrt{100^2 - n^2}}\%$ based on horizontal distances.

$n\%$ $= 100 \times \tan$.

n degrees rise $= (100 \sin n)\%$.

$n\%$ $=$ number of degrees whose sine is $0.01n$.

If n is the **sine of angle**, then the **rise in $\%$** $= 100\ n$.

If n is the **rise in $\%$** , then the **sine** $= 0.01\ n$.

If n is the **tangent of angle**, then the **rise in $\%$** $= \frac{100n}{\sqrt{1 + n^2}}$. Or find from a table the sine corresponding to this tangent, then the **rise in $\%$** $= 100 \times \sin$.

If n is the **rise in $\%$** , then the **tangent of the angle** $= \frac{n}{\sqrt{100^2 - n^2}}$. Or the tangent may be found from a table as that corresponding to **sine** $= 0.01n$.

Approximate: for small angles and for most engineering calculations concerning grades, the sine and the tangent are very nearly equal, hence the simpler of the formulas given above can in most cases be used for both, and no tables are then necessary. Up to a 14% grade (about 8 degrees) the error made thereby is less than 1%.

The actual values given below in the fifteen-column table avoid the calculations with the above reduction factors. Intermediate values sufficiently accurate for most purposes may be found from this table by ordinary interpolation.

Conversion Table for Grades.

For Either Horizontal or Sloping Distances. Tangent or Sine Functions.							For Horizontal Distances Only. Tangent Functions.				For Sloping Distances Only. Sine Functions.			
Percent (%) or Feet per 100 Feet.	Per Mil (‰) or Millimeters per Meter, or Feet per 1000 Feet.	Feet Rise per Foot.	Feet per Mile.	Inches per Mile.	Miles per Foot Rise.	Feet per Foot Rise.	Degrees and Min- utes.	Tan- gent.	Sine.	Equivalent Percent Based on Sloping Distances.	Degrees and Min- utes.	Sine.	Tangent.	Equivalent Percent Based on Horizontal Distances.
1	10	0.01	52.8	633.6	0.018 939 40	100.	0° 34'	0.01	0.010 00	1.000	0° 34'	0.01	0.010 00	1.000
2	20	0.02	105.6	1 267.2	0.009 469 70	50.	1° 9'	0.02	0.020 00	2.000	1° 9'	0.02	0.020 00	2.000
3	30	0.03	158.4	1 900.8	0.006 313 13	33.333 3	1° 43'	0.03	0.029 99	2.999	1° 43'	0.03	0.030 01	3.001
4	40	0.04	211.2	2 534.4	0.004 734 85	25.	2° 17'	0.04	0.039 97	3.997	2° 17'	0.04	0.040 03	4.003
5	50	0.05	264.0	3 168.0	0.003 787 88	20.	2° 52'	0.05	0.049 94	4.994	2° 52'	0.05	0.050 06	5.006
6	60	0.06	316.8	3 801.6	0.003 156 57	16.666 7	3° 26'	0.06	0.059 89	5.989	3° 26'	0.06	0.060 11	6.011
7	70	0.07	369.6	4 435.2	0.002 705 63	14.285 7	4° 0'	0.07	0.069 83	6.983	4° 1'	0.07	0.070 17	7.017
8	80	0.08	422.4	5 068.8	0.002 367 42	12.5	4° 34'	0.08	0.079 75	7.975	4° 35'	0.08	0.080 26	8.026
9	90	0.09	475.2	5 702.4	0.002 104 38	11.111 1	5° 9'	0.09	0.089 64	8.964	5° 10'	0.09	0.090 37	9.037
10	100	0.10	528.0	6 336.0	0.001 893 94	10.	5° 43'	0.10	0.099 50	9.950	5° 44'	0.10	0.100 5	10.05
11	110	0.11	580.8	6 969.6	0.001 721 76	9.090 91	6° 17'	0.11	0.109 3	10.93	6° 19'	0.11	0.110 7	11.07
12	120	0.12	633.6	7 603.2	0.001 578 28	8.333 33	6° 51'	0.12	0.119 1	11.91	6° 54'	0.12	0.120 9	12.09
13	130	0.13	686.4	8 236.8	0.001 456 88	7.692 31	7° 24'	0.13	0.128 9	12.89	7° 28'	0.13	0.131 1	13.11
14	140	0.14	739.2	8 870.4	0.001 352 81	7.142 86	7° 58'	0.14	0.138 6	13.86	8° 3'	0.14	0.141 4	14.14
15	150	0.15	792.0	9 504.0	0.001 262 63	6.666 67	8° 32'	0.15	0.148 3	14.83	8° 38'	0.15	0.151 7	15.17

TIME.

There are in use two different systems of units of time, the **mean solar time** and the **sidereal time**. The mean solar time is based on the apparent motion of the sun with respect to the earth, that is, on the motion of the earth with respect to the sun. The sidereal time is based on the apparent motion of the stars with respect to the earth, that is, on the motion of the earth with respect to the stars.

The **mean solar time** is that indicated by the clocks in common use; it is that which is furnished by the U. S. Naval Observatory and is used in all physical research. In all derived units in use, such as velocities, forces, power, electrical quantities, etc., which involve the element of time, this mean solar time is understood to be meant. According to the National Bureau of Standards, Lord Kelvin (formerly Sir William Thomson), Prof. Walter S. Harshman the Director of the Nautical Almanac, Prof. R. S. Woodward, and other authorities, it is the second of mean solar time which is the unit of time in the centimeter-gram-second system of units. Mean solar time is always understood to be meant in all designations of time unless otherwise specifically stated. In all the units in this book which involve time, the mean solar time is understood.

Sidereal time is used only for astronomical purposes. It is considered as possessing more nearly the essential qualification of a standard unit, namely invariability, but the mean solar time has been adopted instead. However, the relation between the two is known to such a degree of precision, that mean solar time is also perfectly uniform. Tables for interchanging sidereal and mean solar time are given in the American Ephemeris.

Besides these two sets of units of time, there are probably hundreds of other terms used to designate various periods of time, chiefly different kinds of years, months, cycles, etc. These are generally used only in astronomy and history, and many of them are obsolete; they have therefore not been included in the following table.

All the important values in the table have been checked through the kindness of Prof. Walter S. Harshman, Director of the Nautical Almanac; many of these have been accepted as the best obtainable values, and as such are used in the American Ephemeris and Nautical Almanac.

The International Bureau of Weights and Measures has established an important distinction in the notation of time. When it refers to the epoch, that is, the date or time of day, the reference letters are used as indices; and when it refers to the duration of a phenomenon, they are on the same line with the numbers. For instance, an experiment began at 2^h 15^m 46^s lasted 2h 15m 46s, and ended at 4^h 31^m 32^s.

Standard Railway Time in the United States and Canada. On November 18, 1883, a new system of railway time called "Standard Time" went into effect on most of the railroads of the United States and Canada, and has since been adopted by most of the principal cities. According to this system the country is divided into five strips or zones running north and south, each 15° in width. Throughout each strip the time of the clock is the same, and it differs from that in the two neighboring strips by precisely one hour; for instance, when it is 4 o'clock in one strip it is 5 o'clock in the next one east, and 3 o'clock in the next one west.

The following table gives the longitude of the middle line of each strip; the time in that strip is the correct time for that longitude. The actual lines midway between these, where the time changes by one hour, do not always correspond exactly with the theoretical ones, for obvious reasons. The table also gives the name by which that time is designated in each strip and the conventional color by which it is indicated on maps. Eastern time is exactly 5 hours later than Greenwich time.

Mean Longitude West from Greenwich.	Name of Standard Time.	Conventional Color.
60°	Intercolonial time	Brown
75°	Eastern time	Red
90°	Central time	Blue
105°	Mountain time	Green
120°	Pacific time	Yellow

TIME.

Mean solar time is the time in universal use except in astronomy. Unless otherwise stated, mean solar time is understood in this table.

* Accepted by Prof. Walter S. Harshman, Director of the Nautical Almanac.

	Logarithm
1 sidereal second = 0.997 269 57* second (mean solar).....	1.998 8126*
1 second [s] (mean solar) = 1.002 737 91* sidereal seconds.	0.001 1874*
1 sidereal minute = 60.* sidereal seconds.	
1 minute [min or m] (mean solar) = 60.* seconds (mean solar).	
1 sidereal hour = 60.* sidereal minutes, or 3 600.* sidereal seconds.	
1 hour [h] (mean solar):	
= 60.* minutes (mean solar), or 3 600.* seconds (mean solar).	
1 sidereal day:	
= 86 164.1* seconds (mean solar).	
= 86 400.* sidereal seconds.	
= 1 440.* sidereal minutes.	
= 24.* sidereal hours.	
= 23. h, 56. m, 4.091* s (mean solar).	
= 0.997 269 57* day (mean solar).....	1.998 8126*
= 1 mean solar day less 3 m and 55.909* s (mean solar).	
1 day (mean solar):	
= 86 400.* seconds (mean solar).	
= 86 636.555* sidereal seconds.	
= 1 440.* minutes (mean solar).	
= 24.* hours (mean solar).	
= 24. sidereal hours, 3 m, 56.555* s sidereal time.	
= 1.002 737 91* sidereal days.....	0.001 1874*
= 1 sidereal day plus 3. minutes 56.555* seconds sidereal.	
365.242 20* mean solar days = 366.242 20* sidereal days.	
1 civil or calendar day:	
= 1 day (mean solar); is reckoned from mean midnight to mean midnight.	
An apparent solar or a natural day is variable.	
An astronomical or nautical day is reckoned from mean noon to mean noon.	
1 week = 7. days (mean solar).	
1 anomalistic month:	
= 27. days, 13. hours, 18. minutes, 37.4 seconds (mean solar ?).	
1 civil or calendar month [mo]:	
= 28, 29, 30, and 31 days (mean solar).	
= aprx. $\frac{1}{12}$ year (mean solar).	
1 average lunar or synodic month:	
= 29. days, 12. hours, 44. minutes, 2.8* seconds (mean solar).	
= 29.530 59* days (mean solar).	
1 average sidereal month = 27. days, 7. hours, 43. minutes, 11.5* seconds.	
1 lunar year = 354. days, 8. hours, 48. minutes, 34. seconds (mean solar).	
= 12. lunar or synodic months.	
1 common lunar year = 354. days.	
1 year [yr] (mean solar):	
= 366.242 20* sidereal days.	
= 365.242 20* days (mean solar).	
= 365. days, 5. hours, 48. minutes, 46.* seconds (mean solar).	
= 1. sidereal year less 20. minutes, 26.9* seconds (sidereal).	
1 sidereal year:	
= 366.256 399 2* sidereal days.	
= 365.256 360 4* days (mean solar).	
= 365. days, 6. hours, 9. minutes, 9.5* seconds (mean solar).	
= 1. mean solar year plus 20. min, 23.6* sec (mean solar).	
1 civil or calendar year, ordinary = 365.* days (mean solar).	
" leap† = 366.* days (mean solar).	
1 common year = 1. ordinary civil or calendar year.	
1 Julian year = 365.25* days (mean solar).	

† A leap year is one whose number is divisible by 4, except when the number ends in two ciphers, then it must be divisible by 400.

- 1 **Gregorian year** = 365. days, 5. hours, 49. minutes, 12. sec (mean solar).
 1 **tropical or natural year** = 1. year (mean solar).
 1 **anomalous year** = 365. d, 6. h, 13. m, 53.* s (mean solar).
 A **legal year** is obsolete.
 1 **solar cycle** = 28.* Julian years.
 1 **century**† = 100.* civil or calendar years.
 1 **lunisolar cycle** = 532. years.
 1 **millenium** = 1 000. calendar years.

DISCHARGES; FLOW of WATER; IRRIGATION UNITS; VOLUME and TIME. (Volume ÷ time.)

(See also Volumes.)

Discharges (as of water) are generally measured in terms of some volume per second as cubic feet per second, gallons per second, cubic meters per second, etc. The relations between them are therefore the same as between those respective volumes, which see under the units of Volumes. The same is true if they are given per minute. When one is per second and the other per minute, reduce either to the same time as the other and then use the table of volumes.

The only unit differing from these is the miner's inch which is sometimes used in the western United States for measuring the flow of water in streams, particularly for mining. It is a somewhat vague unit, generally insufficiently defined, and has so-called "legal" values in different States, which values differ. Its value varies from about 1.20 to about 1.76 cubic feet per minute; the mean is generally taken as about 1.5; for this value the reduction factors are given in the following table. Aprx. means within 2%.

		Logarithm
1 miner's inch =	1.5 cubic feet per minute.....	0.178 0913
" =	0.187 013 gallon per second. Aprx. $\frac{3}{16}$...	1.271 8717
" =	0.025 cubic foot per second, or $\frac{1}{40}$	2.397 9400
" =	0.000707 925 cb. meters per sec. Ap. $\frac{5}{7000}$..	4.849 9875

The **acre-foot** is sometimes used as a unit for measuring irrigation; it means a body of water 1 acre in area and 1 foot in depth. It is therefore really a true unit of volume. Its chief equivalents are;

1 acre-foot =	325 851. gallons.
" =	43 560. cubic feet.
" =	1 613.33 cubic yards.
" =	1 233.49 cubic meters.

† The twentieth century is generally assumed to have begun with January 1, 1901.

ELECTRIC and MAGNETIC UNITS.

General Remarks.—In the following tables C.G.S. refers to the centimeter-gram-second system of units; **elm**g means electromagnetic; **elst** means electrostatic; **v** means the velocity of light in air, which is here taken as equal to about 3×10^{10} centimeters per second, which value has been included in the logarithms of those relations which involve this **v**; the word “**about**,” used with such derivatives of this velocity, means that they include whatever inaccuracy there is in this velocity. **Aprx.** means that the simple fractions given are correct within 2%. The values of the derived figures in these tables are generally given to six significant figures and seven-place logarithms, even though the original fundamental data may sometimes not warrant such accuracy; the object is to enable the corrections due to any subsequently adopted more accurate fundamental values to be made by mere proportion instead of by complete recalculations.

The **fundamental values** of the electrical units used in these tables are those adopted by the International Electrical Congress at Chicago. Besides the exact values in terms of the C.G.S. units, that Congress also defined certain concrete units as the closest approximations which existed at that time; these concrete units are the ones in use in practice at present. In calculating the relations between the electrical and the mechanical and thermal units like foot-pounds, horse-powers, heat-units, etc., for these tables, it had to be assumed that these concrete units are exactly equal to those defined in terms of the C.G.S. units which they represent, as it would otherwise be impossible to calculate those relations until the differences which may exist between the concrete and the exact values are known; such relations therefore must always involve these differences if they exist; whatever they may be they are absolutely negligible in all but the most refined physical research.

The **absolute values** of the electric units are given for both the usual electromagnetic system and the less usual electrostatic system, but the magnetic units have been confined to those in the electromagnetic system, as the others are rarely if ever used; the dimensional formulas and interrelations of the latter are given in the table of Physical Quantities in the Introduction. In a paper read before the American Institute of Electrical Engineers in July, 1903, Dr. A. E. Kennelly suggests the prefixes **ab-** or **abs-** to the names volt, ohm, etc., to designate the corresponding absolute electromagnetic units; thus **abvolt**, **abohm**, etc., mean the absolute or C.G.S. electromagnetic units. Similarly the prefix **abstat-** designates the corresponding absolute electrostatic units. The suggestion seems a good one, as it is often very convenient to have easily remembered specific names for the absolute electrical units.

The American Institute of Electrical Engineers has adopted the rule that **vector quantities** when used should be denoted by capital italics. This applies chiefly to electromotive force, current, and impedance.

Owing to the numerous important and very useful **interrelations between the various electric and magnetic quantities**, many of which are simple unit relations like Ohm's law or Joule's law, there have been added to the tables of these units numerous formulas giving the relations between quantities measured in terms of various different electric and magnetic units, many of which will frequently be found useful; they are correct numerically also, and may be used like any other formulas. As there is a very large number of such relations, only those likely to be used are given; the others can be readily derived from them. Such relations are usually given in the form of algebraic formulas, but the method adopted here is preferred because it shows directly for what particular units the relations are numerically correct. Treatises on alternating currents should be consulted for the limiting conditions under which these relations apply to alternating or other periodically varying quantities.

The author is indebted to Prof. W. S. Franklin for important suggestions concerning the quantitative interrelations of electric and magnetic units when their intensities are varying or alternating. Also to Dr. Frank A. Wolff, Jr., Assistant Physicist of the National Bureau of Standards, for his kindness in endorsing the correctness of a number of the more important derived values of the electrical units.

Mean, effective and maximum values in periodically varying functions.—With alternating currents the instantaneous values of both the electromotive force and the current vary continually. When the arithmetical mean or average of all these momentary values of the electromotive force or current is taken, it is called the **mean value**; this value is seldom if ever used; for a true alternating current the algebraic mean is always zero for one whole period, hence the arithmetic mean of the whole period or the algebraic or arithmetic mean of half a period is used instead. When the square root of the mean square is used it is called the **effective value**; this is the value almost always used and is the one meant when not otherwise specified; it is this value which corresponds to the electromotive force or current of a direct current circuit in calculations of the energy. Similarly, there is a mean and an effective magnetomotive force, magnetizing force, flux, flux density, etc., but as the arithmetic mean values of these are of less importance the effective values are the ones generally understood unless otherwise specified. By the **maximum value** of any of these is meant the greatest value reached in one period; this value is sometimes the important one, notably in the strain on the insulation, which depends on the maximum electromotive force, or in the calculation of the hysteresis loss, which depends on the maximum flux density. These terms, mean, effective, and maximum, are not used in practice in connection with the power in watts; the **mean watts** are always understood and are equal to the product of the effective volts, the effective amperes, and the cosine of the angle of phase difference.

The following table gives the relations between the maximum, effective, and mean values when the variations follow the sine law. By mean value is here meant that for a half period, as the algebraic mean for a whole period is always zero.

Aprx. means within 2%.

Mean value (half period):	Logarithm
= effective value $\times 0.900\ 316$ (or $(2 \div \pi)\sqrt{2}$). Aprx. subt. 10%.	$\bar{1}.954\ 3951$
= maximum value $\times 0.636\ 620$ (or $2/\pi$). Aprx. $\frac{5}{8}$.	$\bar{1}.803\ 8801$
Effective value:	
= mean value $\times 1.110\ 72$ (or $(\pi \div 4)\sqrt{2}$). Aprx. 1%.	$0.045\ 6049$
= maximum value $\times 0.707\ 107$ (or $\frac{1}{\sqrt{2}}$). Aprx. $\frac{7}{10}$.	$\bar{1}.849\ 4850$
Maximum value:	
= mean value $\times 1.570\ 80$ (or $\pi/2$). Aprx. $1\frac{1}{4}$.	$0.196\ 1199$
= effective value $\times 1.414\ 21$ (or $\sqrt{2}$). Aprx. $1\frac{1}{4}$.	$0.150\ 5150$

RESISTANCE [R, r]; IMPEDANCE [Z, z]; REACTANCE [X, x]. (Electromotive force $\div$ current; length $\times$ resistivity $\div$ cross-section.)

These units are used to measure the opposition offered to the passage of a current through a circuit or part of a circuit. The greater the resistance the greater this opposition. It is similar to the mechanical friction of a moving body, like that of water in a pipe, although the analogy does not extend to the numerical laws, nor are there any specific units for mechanical frictional resistance, as there are for electrical resistance. According to Ohm's law the resistance in ohms is equal to the electromotive force in volts divided by the current in amperes; or according to Joule's law it is equal in ohms to the power in watts divided by the square of the current in amperes; or to the square of the voltage divided by the watts. These relations apply to direct currents, and refer to the true or "ohmic" resistance of the conductor itself, which is dependent only on the material, size, and temperature of the conductor. They also apply to alternating currents when there is no reactance in circuit (caused by inductance or capacity) in which case the effective values of the electromotive force and current, and the true watts, are meant. Resistance refers to a given circuit or part of a circuit, while resistivity (which see) refers to the specific resistance of the material irrespective of the size or shape of the circuit.

Reactance, although not a resistance, and **impedance**, which is often called **apparent resistance**, and is a resistance combined with a reactance, are both correctly measured and expressed in the same units as resistance, namely, ohms, although the reactance depends on the inductance and capacity of the circuit and on the frequency of the alternating current, and is therefore not true resistance. Both of these terms are limited chiefly to alternating current circuits. The impedance in ohms is equal to the effective electromotive force in volts, divided by the effective current in amperes, regardless of what the phase difference may be (that being embraced by the vector character of the impedance). It is also equal to the square root of the sum of the squares of the resistance and the reactance, all being expressed in ohms. For further explanations concerning the calculations of alternating current circuits, reference should be made to treatises on this subject.

In direct current circuits, resistance (true or "ohmic") in ohms is the reciprocal of conductance in mhos; similarly, in alternating current circuits impedance in ohms is the reciprocal of admittance in mhos. When various parts of a circuit are connected in series their total resistance or impedance in ohms is simply the sum of all the individual resistances or impedances in ohms. If they are in parallel or multiple, however, it is best to add their conductances or admittances in mhos and then take the reciprocal of this sum, which will then be the total joint resistance or impedance in ohms.

The unit now universally used is the **ohm**, by which is here meant the **international ohm** of the International Congress of 1893 at Chicago, based on the value 10^9 C.G.S. units, and represented by the resistance of a column of mercury at 0° C., 106.3 centimeters long, weighing 14.4521 grams, and having a uniform cross-section. It was made legal in this country by Congress in 1894 and is adopted by the National Bureau of Standards. The Reichsanstalt has also adopted this value, and there is therefore uniformity in the resistance standards used in those two institutions. The National Bureau of Standards at present uses 1-ohm manganin resistance standards, verified from time to time at the Reichsanstalt, so that the results of the Bureau are at present expressed in terms of the particular mercurial resistance standards of the Reichsanstalt. The construction of primary mercurial standards is about to be undertaken by the Bureau. The British National Physical Laboratory is also undertaking the construction of such standards, and the present definition of the unit of resistance in that country in terms of the Board of Trade ohm and the B. A. units, may be replaced by one in terms of the primary mercurial standard.

In some of the relations with other units, such as the absolute or those of energy, the value of the international ohm as above defined is in the following tables assumed to be equal to the theoretical value, namely, 10^9 electromagnetic C.G.S. units, which value is sometimes called the **true ohm**. In the relations between the international ohm and the other mercury units given in the following table, it is assumed that the uniform cross-section referred to in the definition of the international ohm is one square millimeter.

The **legal ohm** was a mercury standard in use for a number of years prior to the adoption of the international ohm; it differs from the latter only in that the length is 106 centimeters and that its cross-section is defined to be 1 sq. millimeter, while with the international ohm it is the weight which is defined.

The **Siemens unit** formerly used is the resistance of a column of mercury, at 0° C., having a cross-section of one square millimeter and a length of one meter. It was never legalized, but has often been used as a well-defined standard of reference.

The **British Association unit**, or B. A. unit, was formerly the standard in Great Britain; the legal standard now used there is a Board of Trade coil or ohm equal to the international ohm, on the assumed relation that 1 international ohm = 1.013 58 B. A. units. The relation accepted by the National Bureau of Standards is the mean of the relations determined by Glazebrook and by Lindeck in 1892, namely, 1 international (Reichsanstalt) ohm = 1.013 48 B. A. units. The primary standards of the Reichsanstalt, in terms of which this value is given, are themselves subject to various sources of error involved in the construction of such standards.

The electromagnetic C.G.S. unit (or absolute unit) is the resistance through which 1 C.G.S. unit of electromotive force will cause 1 C.G.S. unit of current to flow.

The electrostatic C.G.S. unit (or absolute unit) is similarly defined with respect to the electrostatic units of e.m.f. and current.

RESISTANCE; IMPEDANCE; REACTANCE.

** Accepted by the National Bureau of Standards.

* Checked by Dr. Frank A. Wolff, Jr., Asst. Phys. National Bureau of Standards.

Aprx. means within 2%. By "ohm" is here meant the international ohm, unless otherwise stated. v is the velocity of light.

	Logarithm
1 CGS unit [elmg] = 1 absohm.....	0.000 0000
" = 0.001 microhm.....	3.000 0000
" = 10^{-9} ohm.....	9.000 0000
" = $1/v^2$ CGS unit (elst). About $\frac{1}{9} \times 10^{-20}$...	21.045 7575
1 absohm = 1 CGS unit (elmg).....	0.000 0000
1 microhm = 1 000. CGS units (elmg).....	3.000 0000
" = 0.000 001 ohm.....	6.000 0000
1 Siemens unit (S.U.) = 0.940 734* ohm. Aprx. subtract 6%.	1.973 4667
1 British Association unit [B.A.U.]:	
= 0.986 699** ohm.† Aprx. subtract 1%.....	1.994 1848
= 0.986 602* ohm.† Aprx. subtract 1%.....	1.994 1420
1 legal ohm = 0.997 178* ohm. Aprx. 1.....	1.998 7726
1 ohm = 10^9 CGS units (elmg).....	9.000 0000
" = 10^6 microhms.....	6.000 0000
" = 1.063 00* Siemens units. Aprx. add 6%.....	0.026 5333
" = 1.013 58* British Association units.† Aprx. add 1%.	0.005 8580
" = 1.013 48** British Ass'n units.† Aprx. add 1%.....	0.005 8152
" = 1.002 83* legal ohms. Aprx. 1.....	0.001 2274
" = 10^{-6} megohm.....	6.000 0000
" = $10^9/v^2$ CGS unit (elst). About $\frac{1}{9} \times 10^{-11}$	12.045 7575
1 international ohm = 1 ohm, which see above.	
1 true ohm = 10^9 CGS units (elmg).....	9.000 0000
1 ohm of Reichsanstalt = 1 ohm.....	0.000 0000
1 Board of Trade (Brit.) ohm:†	
= 1.013 58 Brit. Ass'n unit. Aprx. add 1%.....	0.005 8580
= 1 ohm.....	0.000 0000
1 megohm = 10^6 ohms.....	6.000 0000
" = $10^{15}/v^2$ CGS units (elst). About $\frac{1}{9} \times 10^{-5}$	6.045 7575
1 CGS unit (elst) = v^2 CGS units (elmg) About 9×10^{20} .	20.954 2425
" = $v^2 \times 10^{-9}$ ohms. About 9×10^{11}	11.954 2425
" = 1 abstatohm.....	0.000 0000
1 abstatohm = 1 CGS unit (elst).....	0.000 0000
1 absolute unit = 1 CGS unit either elst or elmg.....	0.000 0000

The relations to other measures are as follows: §

Ohms = volts ÷ amperes.

" = volts × seconds ÷ coulombs.

" = volts² ÷ watts.

" = watts ÷ amperes².

" = watts × seconds² ÷ coulombs².

" = volts² × seconds ÷ joules.

" = joules ÷ (amperes² × seconds).

" = joules × seconds ÷ coulombs².

† Mean of Glazebrook's and Lindeek's values of B. A. units in terms of Reichsanstalt primary mercurial standards, accepted by the National Bureau of Standards.

‡ Legal relation in Great Britain.

§ Treatises on alternating currents should be consulted for the limiting conditions under which these relations apply to alternating or other periodically varying quantities.

¶ Latest value, 1903: 1 Reichsanstalt ohm = 1.000 165 Board of Trade ohms.

Ohms resistance:

- = $1 \div \text{mhos conductance}$. For direct currents only.
- = henrys $\div$ time constant in seconds.
- = induced volts $\div$ (rate of change of amperes per second $\times$ time constant in seconds).
- = henrys $\times$ final amperes $\times$ applied volts $\div$ (joules of kinetic energy of the current $\times 2$).
- = applied volts $\times \sqrt{[\text{henrys} \div (\text{joules of kinetic energy of the current} \times 2)]}$.
- = applied volts² $\times$ time constant in seconds $\div$ (joules of kinetic energy of the current $\times 2$).
- = joules of kinetic energy of the current $\times 2 \div$ (time constant in seconds $\times$ final amperes²).
- = (maxwells $\times$ number of turns) $\div$ (final amperes $\times$ time constant in seconds $\times 10$). When the flux is due only to the current, as in self-induction.

Microhms resistance:

- = $1 \div \text{megamhos conductance}$. For direct currents only.

For alternating current circuits: †

Ohms resistance:

- = volts energy component of e.m.f. $\div$ total amperes.
- = watts $\div$ amperes².
- = $\sqrt{(\text{ohms impedance}^2 - \text{ohms reactance}^2)}$.
- = $\sqrt{[(1 \div \text{mhos admittance}^2) - \text{ohms reactance}^2]}$.
- = mhos conductance $\times$ ohms impedance².
- = mhos conductance $\div$ mhos admittance².
- = $\sqrt{(\text{applied volts}^2 - \text{induced volts}^2) \div \text{amperes}}$.
- = applied volts $\div$ (amperes $\times \sqrt{[(\text{time constant in seconds} \times \text{frequency} \times 6.283\ 19\dagger)^2 + 1]}$
- = $\sqrt{[(\text{applied volts} \div \text{amperes})^2 - (\text{henrys} \times \text{frequency} \times 6.283\ 19\dagger)^2]}$.
- = $\sqrt{[\text{ohms impedance}^2 - (\text{henrys} \times \text{frequency} \times 6.283\ 19\dagger)^2]}$.
- = induced volts $\div$ (time constant in seconds $\times$ amperes $\times$ frequency $\times 6.283\ 19\dagger$).

Ohms reactance:

- = volts wattless component of e.m.f. $\div$ total amperes.
- = $\sqrt{(\text{ohms impedance}^2 - \text{ohms resistance}^2)}$.
- = $\sqrt{[(1 \div \text{mhos admittance}^2) - \text{ohms resistance}^2]}$.
- = ohms impedance² $\times$ mhos susceptance.
- = mhos susceptance $\div$ mhos admittance².
- = ohms magnetic reactance - ohms capacity reactance.
- = (henrys $\times$ frequency $\times 6.283\ 19\dagger$) - $[0.159\ 155\dagger \div (\text{farads} \times \text{frequency})]$.

Ohms magnetic reactance = henrys $\times$ frequency $\times 6.283\ 19\dagger$

Ohms capacity reactance = $-0.159\ 155\dagger \div (\text{farads} \times \text{frequency})$.

= $-159\ 155. \div (\text{microfarads} \times \text{frequency})$.

Ohms impedance = total effective volts $\div$ total effective amperes.

- " = $\sqrt{(\text{ohms resistance}^2 + \text{ohms reactance}^2)}$.
- " = $1 \div \text{mhos admittance}$.
- " = $1 \div \sqrt{(\text{mhos conductance}^2 + \text{mhos susceptance}^2)}$.
- " = $\sqrt{(\text{ohms resistance} \div \text{mhos conductance})}$.
- " = $\sqrt{(\text{ohms reactance} \div \text{mhos susceptance})}$.
- " = $\sqrt{[\text{ohms resistance}^2 + (\text{henrys} \times \text{freq.} \times 6.283\ 19\dagger)^2]}$.

† Treatises on alternating currents should be consulted for the limiting conditions under which these relations apply to alternating or other periodically varying quantities.

‡ Or 2π . Aprx. $\frac{5}{8} \times 10$. Log 0.798 1799.

§ Or $1 \div 2\pi$. Aprx. $\frac{8}{5} \div 10$. Log 1.201 8201.

RESISTANCE and LENGTH, for the SAME CROSS-SECTION. (Resistance $\div$ length.)

For wires of the same cross-section and material the following relations exist. Aprx. means within 2%.

	Logarithm
1 ohm per mile:	
= 0.621 370 ohm per kilometer. Aprx. $\frac{5}{8}$	1.793 3503
= 0.000 621 370 ohm per meter. Aprx. $\frac{5}{8} \div 1\ 000$...	4.793 3503
= 0.000 189 394 ohm per foot. Aprx. $19 \div 100\ 000$..	4.277 3661
1 ohm per kilometer:	
= 1.609 35 ohms per mile. Aprx. add $\frac{9}{10}$	0.206 6497
= 0.001 ohm per meter.	3.000 0000
= 0.000 304 801 ohm per foot. Aprx. $3 \div 10\ 000$	4.484 0158
1 ohm per meter = 1 609.35 ohms per mile. Aprx. 1 600....	3.206 6497
" = 1 000. ohms per kilometer.	3.000 0000
" = 0.304 801 ohm per foot. Aprx. $\frac{3}{10}$..	1.484 0158
1 ohm per foot = 5 280. ohms per mile. Aprx. 5 300.	3.722 6339
" = 3 280.83 ohms per klm. Aprx. $\frac{1}{3} \times 10\ 000$..	3.515 9842
" = 3.280 83 ohms per meter. Aprx. $\frac{10}{3}$	0.515 9842

RESISTANCE and CROSS-SECTION, for the SAME LENGTH. (Resistance $\times$ cross-section.)

When the lengths of wires of the same material are the same and the cross-sections are different, the relations between the respective compound units representing the product of the resistance and the cross-section are the same as the relations between the different cross-section units, which see under the units of Surface. Thus if the compound unit **ohm-centimeters²** is the product of the resistance in ohms and the cross-section in square centimeters of any wire, and if similarly **ohm-inches²** is the product of the ohms and the square inches cross-section of another wire of the same length, then 1 ohm-centimeter² = 0.155 000 ohm-inch², in which 0.155 000 is the value of 1 sq. centimeter in sq. inches.

These units are used for converting the values of resistivities from one unit to another (see also under units of Resistivity, below); thus if n is the resistivity of a material in ohm, circular mil, foot, units, and it is required to change this into ohm, sq. mil, foot, units, multiply n by the value of 1 circular mil in square mils as given in the table of units of Surface, namely, 0.785 398.

RESISTIVITY [ρ]; SPECIFIC RESISTANCE. (Resistance $\times$ cross-section $\div$ length.)

These units are used to measure the inherent quality of a material to resist the passage of an electric current. Resistivity differs from resistance in that the latter refers to the number of ohms of any given circuit or part of a circuit, and depends on the length, cross-section, and quality of the material; while resistivity refers only to the nature of the material itself and is always the same for the same material; it is the resistance of a unit amount of the material, like a cube of one centimeter, or a mil-foot, or a meter of one sq. millimeter section. It bears somewhat the same relation to resistance as the density of a material does to the weight of any given

amount of it; the density is always the same for that material, being the weight of a unit of volume, while the total weight of an actual piece depends upon the size of that piece. As the resistivity or specific resistance is a quality of a material, its values are usually given in tables of physical constants; the resistivity may also be calculated from the resistance of any given piece by multiplying this resistance in ohms by the cross-section and dividing by the length; the result will of course be different, depending upon the units used. The resistivity, being a property of a material, is the same for direct as for alternating currents.

There are several units in use. The most rational one is the resistance in ohms between two parallel sides of a cube of one centimeter of the material. This unit is sometimes called the **ohm-centimeter unit**, or **1 ohm per cubic centimeter**, or more correctly, **1 ohm-square-centimeter per centimeter**; it will here be called the **ohm, cubic centimeter, unit**. For most conducting materials in use, except electrolytes, the resistivity when stated in these units is a very small number, hence it is often stated in microhms (millionths of an ohm) instead of ohms.

The **electromagnetic** and the **electrostatic C.G.S. units** are the same as the above except that the resistance is stated in the respective C.G.S. units instead of in ohms.

Another unit in common use is the **meter-millimeter unit**, that is, the resistance in ohms of a wire one meter long and one square millimeter in cross-section; it also has the name **1 ohm per meter per square millimeter**, or more correctly **1 ohm-square-millimeter per meter**; it will here be called the **ohm, square millimeter, meter, unit**. This unit has the advantage that it generally involves less calculation than the cubic-centimeter unit, as the lengths and cross-sections are in practice usually stated in meters and square millimeters when the metric system is used. A more rational unit for circular wires, although apparently not in general use, is similar to this one except that the cross-section is a circle of one millimeter diameter, and is therefore equal to a "circular millimeter" as distinguished from a "square millimeter" (see explanation of circular units under units of Surface). This has the advantage of eliminating from the calculation for the usual round wires the troublesome factor π (or 3.141 59), because when the cross-sections are stated in circular units they are directly equal to the squares of the diameters.

The unit usually used when the lengths are in feet and the diameters in mils (that is, thousandths of an inch), is the **mil-foot or circular mil-foot**, which is the resistance in ohms of a round wire one foot long and one mil in diameter. The cross-section then is one circular mil, and the cross-sections of other round wires are then equal to the squares of their diameters in mils (see explanation in preceding paragraph). This unit also has the name of **1 ohm per foot per circular mil** or **per mil diameter**, or more correctly, **1 ohm-circular-mil per foot**; it will here be called the **ohm, circular mil, foot, unit**. A similar unit, though less frequently used, is the **square mil-foot**; it differs from the other only in that the cross-section is a square mil instead of a circular mil, and it is more convenient to use with bars of rectangular cross-section. It also has the name of **1 ohm per foot per square mil**, or more correctly, **1 ohm-square-mil per foot**; it will here be called the **ohm, square mil, foot, unit**.

Sometimes resistivities are denoted in terms of that of mercury or pure copper as a basis. They are then mere relative resistivities or ratios of two resistivities, that of the material divided by that of mercury or copper, and are therefore not in terms of any real units, although they might be called mercury or copper units. In the following table the resistivities of mercury and of copper have been added to facilitate making calculations with such relative resistivities. The **resistivity of mercury** here used is that deduced from the definition of the concrete international ohm, namely, that a column of uniform cross-section, 106.3 centimeters long, weighing 14.4521 grams, has a resistance of one ohm at 0° C. The cross-section is for this purpose assumed to be one square millimeter. For the **resistivity of pure copper** the Matthiessen value is still in use, namely 1.687 microhms for one centimeter length and one square centimeter cross-section, at 15° C., according to Prof. Lindeck of the Reichsanstalt. Pure copper as now made has a lower resistivity than this; according to Prof. Lindeck the value used in Germany (presumably under the authority of the Reichsanstalt) is 1.667 in the same units.

Aprx. means within 2%. v is the velocity of light.

	Logarithm
1 CGS unit (elmg) = 10^{-9} ohm, cubic centimeter, unit.	9.000 0000
= $1/v^2$ CGS unit (elst). About $\frac{1}{9} \times 10^{-20}$...	21.045 7575
1 ohm, circular mil, foot, unit:	
= 0.785 398 ohm, sq. mil, foot, unit. Aprx. $\frac{8}{10}$	1.895 0899
= 0.166 243 microhm, cb. cm, unit. Aprx. $\frac{1}{6}$	1.220 7433
= 0.002 116 67 ohm, circ. mm, meter, unit. Aprx. $\frac{21}{10}$ 000.	3.325 6534
= 0.001 662 43 ohm, sq. mm, meter, unit. Aprx. $\frac{1}{6} \div 100$..	3.220 7433
1 mil-foot unit. See 1 ohm, circular mil, foot, unit.	
1 ohm-circular-mil per foot. See 1 ohm, circular mil, foot, unit.	
1 ohm per foot per circular mil. See 1 ohm, circular mil, foot, unit.	
1 ohm per foot per mil diameter. See 1 ohm, circular mil, foot, unit.	
1 ohm, sq. mil, foot, unit:	
= 1.273 24 ohm, circular mil, foot, units. Aprx. $\frac{1}{6}$	0.104 9101
= 0.211 667 microhm, cb. cm, unit. Aprx. $21 \div 100$...	1.325 6534
= 0.002 695 03 ohm, circ. mm, met. unit. Aprx. $\frac{8}{3} \div 1$ 000.	3.430 5635
= 0.002 116 67 ohm, sq. mm, met. unit. Aprx. $21 \div 10$ 000.	3.325 6534
1 ohm-sq. mil per foot. See 1 ohm, sq. mil, foot, unit.	
1 ohm per foot per sq. mil. See 1 ohm, sq. mil, foot, unit.	
1 microhm, cb. centimeter, unit:	
= 1 000. CGS units (elmg).....	3.000 0000
= 6.015 29 ohm, circular mil, foot, units. Aprx. 6....	0.779 2567
= 4.724 40 ohm, sq. mil, foot, units. Aprx. $\frac{1}{21} \times 100$..	0.674 3466
= 0.012 732 4 ohm, circ. mm, met. unit. Aprx. $\frac{1}{8} \div 10$...	2.104 9101
= 0.01 ohm, sq. mm, meter, unit.	2.000 0000
= 10^{-6} ohm, cb. cm, unit.	6.000 0000
1 microhm-sq. centimeter per centimeter. See 1 microhm, cb. cm, unit.	
1 microhm per cubic centimeter. See 1 microhm, cb. cm, unit.	
1 ohm, circular mm, meter, unit:	
= 472.440 ohm, circ. mil, ft, units. Aprx. $\frac{10}{21}$ 000.	2.674 3466
= 371.054 ohm, sq. mil, ft, units. Aprx. $\frac{3}{8} \times 1$ 000	2.569 4365
= 78.539 8 microhm, cb. cm, units. Aprx. 80.....	1.895 0899
= 0.785 398 ohm, sq. mm, meter, unit. Aprx. $\frac{8}{10}$...	1.895 0899
= 0.000 078 539 8 ohm, cb. cm, unit. Aprx. $80 \div 1$ 000 000.	5.895 0899
1 ohm-circular-mm per meter. See 1 ohm, circular mm, meter, unit.	
1 ohm per meter per circular mm. See 1 ohm, circular mm, meter, unit.	
1 ohm, sq. mm, meter, unit:	
= 601.529 ohm, circular mil, foot, units. Aprx. 600....	2.779 2567
= 472.440 ohm, sq. mil, foot, units. Aprx. $\frac{1}{21} \times 10$ 000..	2.674 3466
= 100. microhm, cb. cm, units.	2.000 0000
= 1.273 24 ohm, circular mm, meter, units. Aprx. $\frac{1}{6}$...	0.104 9101
= 0.000 1 ohm, cb. centimeter, unit.	4.000 0000
1 ohm-sq. mm per meter. See 1 ohm, sq. mm, meter, unit.	
1 ohm per meter per sq. mm. See 1 ohm, sq. mm, meter, unit.	
1 ohm, cb. centimeter, unit:	
= 10^9 CGS units (elmg).....	9.000 0000
= 1 000 000. microhms, cb. cm, units.	6.000 0000
= 12 732.4 ohm, circ. mm, met. units. Aprx. $\frac{1}{8} \times 100$ 000.	4.104 9101
= 10 000. ohm, sq. mm, meter, units.	4.000 0000
= $10^9/v^2$ CGS unit (elst). About $\frac{1}{9} \times 10^{-11}$	12.045 7575
1 ohm-sq. cm per cm. See 1 ohm, cb. centimeter, unit.	
1 ohm per cubic centimeter. See 1 ohm, cb. cm, unit.	
1 megohm, cb. centimeter, unit:	
= 1 000 000. ohm, cb. cm, units.....	6.000 0000
1 CGS unit (elst) = v^2 CGS units (elmg). About 9×10^{20}	20.954 2425
" = $v^2 \times 10^{-9}$ ohm, cb. cm, units. Abt. 9×10^{11}	11.954 2425
" = $v^2 \times 10^{-15}$ megohm, cb. cm, units. About 9×10^5	5.954 2425

When resistivities, or specific resistances, are given in terms of copper or mercury, then multiply them by the reduction factors in the following table to reduce them to the corresponding values in the respective units.

		Logarithm
Resistivity of copper: †		
=	10.027 5 ohm, circular mil, foot, units.....	1.001 1923
=	7.875 57 ohm, sq. mil, foot, units.....	0.896 2822
=	1.667 † microhm, cb. cm, units.....	0.221 9356
=	0.021 224 9 ohm, circular mm, meter, unit.....	2.326 8457
=	0.017 720 2 times that of mercury.....	2.248 4689
=	0.016 67 ohm, sq. mm, meter, unit.....	2.221 9356
=	0.000 001 667 ohm, cb. cm, unit.....	6.221 9356
Resistivity of copper (Matthiessen): ‡		
=	10.147 8 ohm, circular mil, foot, units.....	1.006 3718
=	7.970 06 ohm, sq. mil, foot, units.....	0.901 4617
=	1.687 ‡ microhm, cb. cm, units.....	0.227 1157
=	0.021 479 5 ohm, circular mm, meter, unit.....	2.332 0252
=	0.017 932 8 times that of mercury.....	2.253 6484
=	0.016 87 ohm, sq. mm, meter, unit.....	2.227 1151
=	0.000 001 687 ohm, cb. cm, unit.....	6.227 1151
Resistivity of mercury: §		
=	565.879 ohm, circular mil, foot, units.....	2.752 7234
=	444.40 ohm, sq. mil, foot, units.....	2.647 8133
=	94.073 4 microhm, cb. cm, units.....	1.973 4667
=	56.432 7 times that of copper.....	1.751 5311
=	55.763 7 times that of copper (Matthiessen)....	1.746 3516
=	1.197 78 ohm, circular mm, meter, units.....	0.078 3768
=	0.940 734 § ohm, sq. mm, meter, unit.....	1.973 4667
=	0.000 094 073 4 ohm, cb. cm, unit.....	5.973 4667

The relations of resistivity to other measures are as follows:

Resistivity (in ohm, cb. cm, units) = $1 \div$ conductivity (in mho, cb. cm units).
 " " " = ohms $\times$ sq. cm section $\div$ cm length.

CONDUCTANCE [G, g]; **ADMITTANCE** [Y, y]; **SUSCEPTANCE** [B, b]. (Current $\div$ electromotive force; $1 \div$ resistance; cross-section $\times$ conductivity $\div$ length.)

These units are used to measure the quality of a circuit or part of a circuit to conduct a current; the greater the conductance the better does the circuit conduct. For direct current circuits it is the reciprocal or opposite of resistance, which see. There appears to be no mechanical analogy, as in mechanics the opposite quality, namely, the mechanical resistance, is used. Conductances are not often used in calculations, as the resistances are generally used by preference. When, however, there are several circuits in parallel or multiple arc, the calculation of their joint action is simpler if made with conductances, as their joint conductance is then merely the sum of the individual conductances, while when resistances are used the joint resistance is equal to the reciprocal of the sum of the reciprocals of the individual resistances.

For direct current circuits, or when there is no reactance in alternating current circuits, the conductance in mhos is equal to the reciprocal of the resistance in ohms. It follows from Ohm's law that for direct current circuits, and for alternating current circuits without reactance, the conductance in mhos is equal to the current in amperes divided by the electromotive force in volts. The conductance in mhos is also equal to the resistance in ohms divided by the sum of the squares of the resistance in ohms and the reactance in ohms. The relations to joules and watts are rarely if ever used.

† Pure copper at 15° C.: according to Prof. Lindeck.

† Matthiessen's value for pure copper at 15° C.; according to Prof. Lindeck.

§ Pure mercury at 0° C., based on definition of international ohm.

Admittance, which is the reciprocal of impedance, and **susceptance**, which together with conductance make admittance, are both correctly expressed and measured in the same units as conductances, namely, mhos, although they depend on the inductance and capacity of the circuit and on the frequency of the alternating current and are therefore not true conductances. Both of these terms are limited chiefly to alternating current circuits. The admittance in mhos is equal to the effective current in amperes divided by the effective electromotive force in volts, regardless of what the phase difference may be; its value in mhos is equal to the reciprocal of the impedance in ohms. It is also equal to the square root of the sum of the squares of the conductance and the susceptance, all values being in mhos. The susceptance in mhos is equal to the wattless current in amperes divided by the electromotive force in volts. It is also equal in mhos to the reactance in ohms divided by the sum of the squares of the resistance in ohms and the reactance in ohms. For further explanations concerning the calculation of alternating current circuits reference should be made to treatises on that subject.

The only unit used in practice is the **mho**, which is the reciprocal of the ohm; it is the word ohm written reversed to indicate the reciprocal. There is no official sanction for its use, but as there is no other practical unit, it has come into use.

The **electromagnetic** and **electrostatic C.G.S. units** are the reciprocals of the corresponding units of resistance. v is the velocity of light.

	Logarithm
1 CGS unit (elst) = $10^9/v^2$ mho. About $\frac{1}{9} \times 10^{-11}$	12.045 7575
" = $1/v^2$ CGS unit (elmg). About $\frac{1}{9} \times 10^{-20}$	21.045 7575
1 mho = $v^2 \times 10^{-9}$ CGS units (elst). About 9×10^{11}	11.954 2425
" = 10^{-9} CGS unit (elmg).....	9.000 0000
1 megamho = 1 000 000. mhos.....	6.000 0000
" = 0.001 CGS unit (elmg).....	3.000 0000
1 CGS unit (elmg) = v^2 CGS units (elst). About 9×10^{20} ..	20.954 2425
" = 10^9 mhos.....	9.000 0000
" = 1 000. megamhos.....	3.000 0000

The relations to other measures are as follows. † (See also the reciprocals of those under resistance.)

Mhos = $1 \div$ ohms.

" = amperes $\div$ volts.

" = watts $\div$ volts².

" = amperes² $\div$ watts.

Megamhos = $1 \div$ microhms.

Mhos conductance:

= $1 \div$ ohms resistance. For direct currents only.

= amperes energy component of current $\div$ volts total e.m.f.

= watts $\div$ volts².

= $\sqrt{(\text{mhos admittance}^2 - \text{mhos susceptance}^2)}$.

= $\sqrt{[(1 \div \text{ohms impedance}^2) - \text{mhos susceptance}^2]}$.

= ohms resistance $\div$ ohms impedance².

= ohms resistance $\div$ (ohms resistance² + ohms reactance²).

= ohms resistance $\times$ mhos admittance².

Mhos susceptance:

= amperes wattless component of current $\div$ volts total e.m.f.

= $\sqrt{(\text{mhos admittance}^2 - \text{mhos conductance}^2)}$.

= $\sqrt{[(1 \div \text{ohms impedance}^2) - \text{mhos conductance}^2]}$.

= ohms reactance $\div$ ohms impedance².

= ohms reactance $\div$ (ohms resistance² + ohms reactance²).

= ohms reactance $\times$ mhos admittance².

Mhos admittance = total effective amperes $\div$ total effective volts.

" = $\sqrt{(\text{mhos conductance}^2 + \text{mhos susceptance}^2)}$.

" = $1 \div$ ohms impedance.

" = $1 \div \sqrt{(\text{ohms resistance}^2 + \text{ohms reactance}^2)}$.

" = $\sqrt{(\text{mhos conductance} \div \text{ohms resistance})}$.

" = $\sqrt{(\text{mhos susceptance} \div \text{ohms reactance})}$.

† Treatises on alternating currents should be consulted for the limiting conditions under which these relations apply to alternating or other periodically varying quantities.

CONDUCTIVITY [γ]; SPECIFIC CONDUCTANCE.(Conductance $\times$ length $\div$ cross-section; $1 \div$ resistivity.)

These units are used to measure the inherent quality of a material to conduct an electric current. Conductivity, which is the reciprocal of resistivity, differs from conductance in that the latter applies to a given circuit or part of a circuit, and its amount depends on the length, cross section, and quality of the material; while conductivity refers only to the nature of the material and is always the same for the same material; it is the conductance of a unit amount of the material like a cube of one centimeter. It bears somewhat the same relation to conductance as the density of a material does to the weight of a given amount of it; the density is always the same for that material, being the weight of a unit of volume, while the total weight of an actual piece depends on the size of that piece. As the conductivity is a quality of a material, its values are usually given in tables of physical constants. The conductivity may also be calculated from the conductance of any piece or part of a circuit by multiplying the conductance in mhos (or $1 \div$ resistance in ohms) by the length and dividing by the cross-section; the result will of course be different depending upon the units used. The conductivity, being a property of a material, is the same for direct and for alternating current.

The values of the conductivities of materials are not in general use, the reciprocal quantity, namely resistivity, being generally preferred, as it is simpler to use in most calculations. The use of conductivities in practice is generally limited to electrolytes and for making comparisons of other conducting materials with copper, or for comparing different qualities of copper with each other.

The most rational unit and the one which seems to be coming into more general use, is the conductivity of a material of which a cube of one centimeter has a conductance of one mho between two parallel sides. It will here be called the **mho, cubic centimeter, unit**. This means that the resistance of a column of that material one centimeter long and one square centimeter cross-section, is one ohm, that is, it corresponds to the ohm, cubic centimeter, unit of resistivity; conductivities stated in the mho, cubic centimeter, unit are the numerical reciprocals of the resistivities stated in the ohm, cubic centimeter, unit. This unit of conductivity is therefore the best one to use when conductivities are to be converted into resistivities or the reverse. This unit is used chiefly for electrolytes; the best conducting aqueous solutions of acids at 40° C. have a conductivity of about one, in terms of this unit.

The **electromagnetic C.G.S. unit** is the same, except that the conductance is stated in C.G.S. units instead of mhos. Similarly with the **electrostatic C.G.S. unit**.

The conductances in mhos of a wire one meter long and one square millimeter or one circular millimeter cross-section, or one foot long and one square mil or one circular mil cross-section, may also be used as units of conductivity, each being the reciprocal of the corresponding unit of resistivity, which see.

The most usual way of stating the conductivity of a solid material is to give the ratio of its conductivity to that of pure copper as a standard; this avoids the use of the little-known unit of conductance (mho). This ratio is usually given as a percent, but may also be stated as so-and-so many "copper units" of conductivity. The Matthiessen value for the resistivity of pure copper at 15° C. is, according to Prof. Lindeck of the Reichsanstalt, 1 687 in microhm, cubic centimeter, units. The conductivity corresponding to this is 592 768. in mho, cubic centimeter, units. In the following table this is called the **copper unit** (Matthiessen). Better qualities of copper are now made, which explains the apparent anomaly of conductivities greater than 100% when based on the Matthiessen standard. A better value for pure copper is the one used as standard in Germany, presumably by authority of the Reichsanstalt, which according to Prof. Lindeck is a resistivity of 1 667 in microhm, cubic centimeter, units, at 15° C. The

conductivity corresponding to this is 599 880. in mho, cubic centimeter, units. In the following table this is called the **copper unit**. Mercury was formerly often used as a standard of comparison, particularly in stating the conductivities of electrolytes. The resistivity determined from the definition of the international ohm is 94.073 4 in microhm, cubic centimeter, units. The conductivity corresponding to this is 10 630. in mho, cubic centimeter, units. In the following table this is called the **mercury unit**.

	Logarithm
1 CGS unit (elst):	
= $10^9/v^2$ mho, cb. cm, unit. About $\frac{1}{9} \times 10^{-11}$	12.045 7575
= 94 073.4/ v^2 mercury unit. About $1.045\ 26 \times 10^{-16}$	16.019 2242
= $1/n^2$ CGS unit (elmg). About $\frac{1}{9} \times 10^{-23}$	21.045 7575
1 mho, cb. centimeter, unit:	
= $v^2 \times 10^{-9}$ CGS units (elst). About 9×10^{11}	11.954 2425
= 0.000 094 073 4 mercury unit.....	5.973 4667
= 0.000 001 687 copper unit (Matthiessen).....	6.227 1151
= 0.000 001 667 copper unit.....	6.221 9356
= 10^{-9} CGS unit (elmg).....	9.000 0000
1 mercury unit:	
= $v^2 \times 1.063\ 0 \times 10^{-5}$ CGS units (elst). Ab. $9.567\ 000 \times 10^{15}$	15.980 7758
= 10 630. mho, cb. cm, units.....	4.026 5333
= 0.017 932 8 copper unit (Matthiessen).....	2.253 6484
= 0.017 720 2 copper unit.....	2.248 4689
= 0.000 010 630 CGS unit (elmg).....	5.026 5333
1 copper unit (Matthiessen):	
= 592 768. mho, cb. cm, units.....	5.772 8849
= 55.763 7 mercury units.....	1.746 3519
= 0.000 592 768 CGS unit (elmg).....	4.772 8849
1 copper unit =	
= 599 880. mho, cb. cm, units.....	5.778 0644
= 56.432 7 mercury units.....	1.751 5311
= 0.000 599 880 CGS unit (elmg).....	4.778 0644
1 CGS unit (elmg) =	
= v^2 CGS units (elst). About 9×10^{23}	20.954 2425
= 10^9 mho, cb. cm, units.....	9.000 0000
= 94 073.4 mercury units.....	4.973 4667
= 1 687. copper units (Matthiessen).....	3.227 1151
= 1 667. copper units.....	3.221 9356

Conductivity of mercury: †	
= 10 630. mho, cb. centimeter, units.....	4.026 5333
= 0.017 932 8 times that of copper (Matthiessen).....	2.253 6484
= 0.017 720 2 times that of copper.....	2.248 4689

Conductivity of copper (Matthiessen): †	
= 592 768. mho, cb. centimeter, units.....	5.772 8849
= 55.763 7 times that of mercury.....	1.746 3516

Conductivity of copper: §	
= 599 880. mho, cb. centimeter, units.....	5.778 0644
= 56.432 7 times that of mercury.....	1.751 5311

The relations of conductivity to other measures are as follows:

Conductivity (in mho, cb. cm, units):	
= $1 \div$ resistivity (in ohm, cb. cm, units).	
= mhos $\times$ cm length $\div$ sq. cm section.	
= cm length $\div$ (ohms $\times$ sq. cm section).	

† Pure mercury at 0° C.; based on the definition of the international ohm.
 † Matthiessen's value for pure copper at 15° C.; according to Prof. Lindeck.
 § Pure copper at 15° C.; according to Prof. Lindeck.

ELECTROMOTIVE FORCE [e.m.f., E , e]; **POTENTIAL**; **DIFFERENCE OR FALL OF POTENTIAL** [p , d , U , u]; **STRESS**; **ELECTRICAL PRESSURE**; **VOLTAGE**. (Magnetic flux $\div$ time; current $\times$ resistance.)

These units are used to measure the electrical pressure, stress, or motive force which produces or tends to produce a current, just as pounds measure the pressure of air either in the form of compressed air or wind, or as the differences of level of water measure the force which causes the water to flow and which might similarly be called the hydraulic motive force. According to Ohm's law the electromotive force in volts is equal to the current in amperes multiplied by the resistance in ohms; or according to Joule's law it is equal to the power in watts divided by the amperes; or to the square root of the product of the watts and the ohms; these apply to the electromotive forces or differences of potential of direct currents; they apply to alternating current electromotive forces also when there is no reactance in the circuit and therefore no phase shifting (caused by inductance or capacity), in which case they refer to the effective electromotive force; when there is reactance in such circuits the electromotive force in volts equals the current in amperes multiplied by the impedance in ohms.

The terms **electromotive force** and **potential** are used synonymously in practice, although the use of the latter term is not to be commended owing to its more general meaning in physics. **Difference of potential** means in general the difference between two absolute potentials, e.m.f.'s, or potentials in general, the actual values of which need not be known; this term is often distinguished from electromotive force, in that the latter applies to the total which is generated in a battery or dynamo while the difference of potential applies only to a portion of it, like that available at the terminals, or that between any two points on a circuit. **Voltage** means any e.m.f. or difference of potential when expressed in volts. **Absolute potential** is sometimes used to denote the potential above or below some assumed zero, which is usually taken as that of the earth.

The unit universally used is the **volt**, by which is here meant the international volt of the International Congress of 1893 in Chicago, defined as that electromotive force which will maintain one international ampere through one international ohm, represented for practical purposes by $1 + 1.434$ of that of a Clark cell at $15^{\circ}\text{C}.$ † It was made legal in this country by Congress in 1894, and is adopted by the National Bureau of Standards. The "saturated" Weston or cadmium standard cell (with excess of crystals) may eventually be substituted for the Clark cell as the official standard because it has a much smaller temperature coefficient (see table below); the relation between the Clark and this Weston cell being known quite definitely (see table below), either may be used as the standard; in this table this ratio and the value of the Clark cell are used as the fundamental values. There is another type of cadmium cell called the "unsaturated" Weston cell, in which there is no excess of crystals at ordinary temperatures, as the solution is saturated at $4^{\circ}\text{C}.$; this has the advantage of having a still lower temperature coefficient, which can be neglected entirely at ordinary temperatures; the National Bureau of Standards does not regard it safe to assign a definite value to this unsaturated Weston cell owing to the possibility of the seal being imperfect and the consequent change in the concentration of the solution, and also the impossibility of ascertaining the exact temperature at which the solution was saturated. The e.m.f. of this cell, with a solution saturated at $4^{\circ}\text{C}.$, is, however, 1.019 8 international volts, this value being the same as that of the saturated cell at the same temperature. A number of such cells belonging to the Bureau have been intercompared; and were found to differ by a number of units

† This is the value of the volt used in calibrating the Weston voltmeters.

in the last decimal place; hence the cell should not be employed as a standard of reference, although as a working standard it can hardly be improved upon.

The value adopted at the Reichsanstalt for the electromotive force of the Clark cell is based upon a determination of its e.m.f. in terms of the electrochemical equivalent of silver and the unit of resistance, and also upon a similar determination of the e.m.f. of the Weston or cadmium cell, together with a determination of the ratio of the values of these two cells. As the values thus obtained for the Clark and Weston or cadmium cells by the silver voltmeter did not agree with the directly determined ratio, each of the silver voltmeter determinations was given equal weight and the two separate values adjusted so as to give the ratio directly determined. The Reichsanstalt's value thus obtained for the Clark cell is 1.432 85 instead of 1.434 as defined by the International Congress and legal in this country.† This Reichsanstalt value may be more accurate, but is not legalized here. As the cells are the same, this makes a very slight difference between the volt used by the Reichsanstalt and that legal and used in this country (the international volt). The National Bureau of Standards uses as the fundamental units those of resistance and electromotive force, obtaining the ampere from them, thus bringing all three into agreement with each other. According to Weston the international concrete volt, ampere, and ohm, as defined by the Chicago Congress, agree with each other.

In some of the relations with other units, such as the absolute, the magnetic, the energy units, etc., the value of the international volt as above defined in terms of the Clark cell is in the following tables assumed to be equal to the theoretical value, namely 10^8 electromagnetic C.G.S. units, which value is sometimes called the **true volt**. According to the theoretical definition of a volt, it is the difference of potential generated in a conductor which cuts 10^8 C.G.S. units of magnetic flux (or 10^8 maxwells or lines of force) per second; or it is the difference of potential generated per centimeter length of a conductor moving transversely through a magnetic field of a density of 1 C.G.S. unit of density (or 1 gauss) at a velocity of 10^8 centimeters (or 1 000 kilometers) per second. A difference of potential thus generated is moreover directly proportional to the amount of magnetic flux traversed per second. In the older literature the e.m.f. of a Daniell cell (about 1.1 volt) was often used as a unit.

The **electromagnetic C.G.S. unit** (or absolute unit) is the difference of potential generated at the ends of a conductor 1 centimeter long moving through a magnetic field of unit density (one gauss) at a speed of 1 centimeter per second perpendicularly to the direction of the field; or more briefly, it is the difference of potential induced in a conductor which cuts one unit of magnetic flux (one maxwell or one line of force) per second.

The **electrostatic C.G.S. unit** (or absolute unit) is that difference of potential through which one electrostatic unit of quantity falls when the work done by it is one erg.

ELECTROMOTIVE FORCE.

** Accepted by the National Bureau of Standards.

* Checked by Dr. Frank A. Wolff, Jr., Asst. Phys. National Bureau of Standards.

Apix. means within 2%. By "volt" is meant international volt unless otherwise stated. v is the velocity of light.

	Logarithm
1 CGS unit (elmg) = 1 abvolt.....	0.000 0000
" = 0.01 microvolt	2.000 0000
" = 10^{-8} volt.....	8.000 0000
" = $1/v$ CGS unit (elst). About $\frac{1}{9} \times 10^{-10}$...	11.522 8787
1 abvolt = 1 CGS unit (elmg).....	0.000 0000
1 microvolt = 100. CGS units (elmg).....	2.000 0000
" = 0.000 001 volt	6.000 0000
1 millivolt = 0.001 volt.....	3.000 0000
1 legal volt = 0.997 178* volt. Apix. 1	1.998 7726
" = 1 ampere $\times$ 1 legal ohm.	

† The difference corresponds almost exactly to that due to one Centigrade degree difference of temperature; it is about 8 hundredths of one percent.

1 volt [V, v]:	Logarithm
= 10^8 CGS units (elmg).....	8.000 0000
= 1 000 000. microvolts.....	6.000 0000
= 1 000. millivolts.....	3.000 0000
= 1.002 83* legal volts. Aprx. 1.....	0.001 2274
= 0.999 198** volt of Reichsanstalt.† Aprx. subtr. $\frac{8}{100}\%$..	1.999 6516
= 0.980 962** Weston (satur.) cell at 20° C. Ap. sub. 2%...	1.991 6523
= 0.980 567 Weston (unsat.) cell at any temp.† Aprx. subtr. 2%.....	1.991 4774
= 0.697 350* Clark cell at 15° C. Aprx. $\frac{7}{10}\%$	1.843 4508
= $10^8/v$ CGS unit (elst). About $\frac{1}{300}$	3.522 8787
= 0.001 kilovolt.....	3.000 0000
1 international volt = 1 volt, which see above.....	0.000 0000
1 true volt = 10^8 CGS units (elmg).....	8.000 0000
1 volt of Reichsanstalt = 1.000 803** volts.† Ap. add $\frac{8}{100}\%$..	0.000 3484
1 Weston (cadmium; saturated) cell at 20° C. with excess of crystals:	
= 1.019 4** volts. Aprx. add 2%.....	0.008 3477
= 1.018 6** volts of Reichsanstalt. Aprx. add 2%	0.007 9993
= 0.710 88* Clark cell at 15° C. Aprx. $\frac{5}{7}\%$	1.851 7935
1 Weston (cadmium; unsaturated†) cell at any ordinary temperature:	
= 1.019 8* volts. Aprx. add 2%.....	0.008 5226
= 1.019 0* volts of Reichsanstalt. Aprx. add 2%.....	0.008 1742
1 Daniell cell = 1.1 volts approximately (unreliable)	0.041 3927
1 Clark cell at 15° C.:	
= 1.434** volts. Aprx. $\frac{10}{7}\%$	0.156 5492
= 1.432 85** volts of Reichsanstalt. Aprx. $\frac{10}{7}\%$	0.156 2008
= 1.406 7** Weston cells at 20° C Aprx. $\frac{7}{5}\%$	0.148 2015
1 CGS unit (elst) = v CGS units (elmg). Ab. 3×10^{10} .	10.477 1213
" = $v \times 10^{-8}$ volts. About 300.....	2.477 1213
" = 1 abstavolt.....	0.000 0000
" = $v \times 10^{-11}$ kilovolt. About $\frac{3}{10}$	1.477 1213
1 abstavolt = 1 CGS unit (elst).....	0.000 0000
1 kilovolt = 1000. volts.....	3.000 0000
" = $10^{11}/v$ CGS units. (elst). About $\frac{10}{3}$	0.522 8787
1 megavolt = 1 000 000. volts.....	6.000 0000
1 absolute unit = 1 CGS unit, either elmg or elst.....	0.000 0000

The relations of volts to other measures are as follows: †

Volts = amperes $\times$ ohms.

" = ohms $\times$ coulombs $\div$ seconds.

" = watts $\div$ amperes.

" = kilowatts $\times$ 1 000. $\div$ amperes.

" = $\sqrt{(\text{watts} \times \text{ohms})}$.

" = watts $\times$ seconds $\div$ coulombs.

" = joules $\div$ coulombs.

" = joules $\div$ (amperes $\times$ seconds).

" = $\sqrt{(\text{joules} \times \text{ohms} \div \text{seconds})}$.

" = coulombs $\div$ farads.

" = coulombs $\times$ 1 000 000. $\div$ microfarads.

" = $\sqrt{(\text{joules of stored energy} \times 2 \div \text{farads})}$.

" = 1 000. $\times \sqrt{(\text{joules of stored energy} \times 2 \div \text{microfarads})}$.

" = maxwells $\times$ number of turns $\div$ (seconds $\times 10^3$).

" = gaussses $\times$ sq. centimeters $\div$ (seconds $\times 10^3$).

Induced volts:

= henrys $\times$ rate of change of amperes per second.

= time constant in seconds $\times$ ohms $\times$ rate of change of amperes per sec.

Applied volts:

= henrys $\times$ final amperes $\div$ time constant in seconds.

= joules of kinetic energy of the current $\times$ ohms $\times 2 \div$ (henrys $\times$ final amperes).

= ohms $\times \sqrt{(\text{joules of kinetic energy of the current} \times 2 \div \text{henrys})}$.

= joules of kinetic energy of the current $\times 2 \div$ (time constant in seconds $\times$ final amperes).

= $\sqrt{[(\text{joules of kinetic energy of the current} \times \text{ohms} \times 2) \div \text{time constant in seconds}]}$.

† See explanatory note above.

† Consult treatises on alternating currents for the limiting conditions.

For alternating current circuits: †

$$\text{Volts} = \text{watts} \div (\text{amperes} \times \cos \phi^\ddagger)$$

$$= \sqrt{[(\text{watts} \times \text{ohms}) \div \cos \phi^\ddagger]}$$

$$= \text{amperes} \div (\text{farads} \times \text{frequency} \times 6.283\ 19\%)$$

$$= \text{amperes} \times 1\ 000\ 000. \div (\text{microfarads} \times \text{frequency} \times 6.283\ 19\%).$$

Induced volts:

$$= \sqrt{[(\text{applied volts})^2 - (\text{amperes} \times \text{ohms resistance})^2]}.$$

$$= \text{henrys} \times \text{amperes} \times \text{frequency} \times 6.283\ 19\%.$$

$$= \text{time constant in seconds} \times \text{ohms resistance} \times \text{amperes} \times \text{frequency} \times 6.283\ 19\%.$$

Applied volts:

$$= \sqrt{[(\text{amperes} \times \text{ohms resistance})^2 + (\text{induced volts})^2]}.$$

$$= \text{amperes} \times \sqrt{[(\text{henrys} \times \text{frequency} \times 6.283\ 19\%)^2 + (\text{ohms resistance})^2]}.$$

$$= \text{amperes} \times \text{ohms resistance} \times \sqrt{[(\text{time constant in seconds} \times \text{frequency} \times 6.283\ 19\%)^2 + 1]}.$$

Formulas for the temperature corrections in Centigrade degrees, between 0° and 30° , determined by the Reichsanstalt and accepted by the National Bureau of Standards. They apply equally well to the international values and to the Reichsanstalt values. t is the temperature in Centigrade degrees; E_t is the electromotive force at that temperature; while E_{15} and E_{20} are the standard values at 15° and 20° respectively, as given in the above table.

For the Clark cell:

$$E_t = E_{15} - 0.001\ 19 (t - 15) - 0.000\ 007 (t - 15)^2. **$$

For the Weston (saturated) cell:

$$E_t = E_{20} - 0.000\ 038 (t - 20) - 0.000\ 000\ 65 (t - 20)^2. **$$

E.M.F. of Clark and Weston Cells at Different Temperatures
Calculated from these Formulas.

C°	F°.	Clark.		Weston (saturated).	
		International Volts.	Reichsanstalt Volts.	International Volts.	Reichsanstalt Volts.
0	32.0	1.4503	1.4491 2	1.0199	1.0191
10	50.0	1.4398	1.4386 2	1.0197	1.0189
13	55.4	1.4364	1.4352 0	1.0196	1.0188
14	57.2	1.4352	1.4340 3	1.0196	1.0188
15	59.0	1.4340	1.4328 5	1.0196	1.0188
16	60.8	1.4328	1.4316 5	1.0195	1.0187
17	62.6	1.4316	1.4304 4	1.0195	1.0187
18	64.4	1.4304	1.4292 2	1.0195	1.0187
19	66.2	1.4291	1.4279 8	1.0194	1.0186
20	68.0	1.4279	1.4267 3	1.0194	1.0186
21	69.8	1.4266	1.4254 6	1.0194	1.0186
22	71.6	1.4253	1.4241 8	1.0193	1.0185
23	73.4	1.4240	1.4228 8	1.0193	1.0185
24	75.2	1.4227	1.4215 7	1.0192	1.0184
30	86.0	1.4146	1.4134 3	1.0190	1.0182

† Treatises on alternating currents should be consulted for the limiting conditions under which these relations apply to alternating or other periodically varying quantities.

‡ ϕ is the phase difference in degrees.

§ Or 2π . Aprx. $\frac{5}{8} \times 10$. Log. 0.798 1799.

ELECTRICAL CURRENT [I, i]; CURRENT STRENGTH or INTENSITY. (Electromotive force $\div$ resistance; quantity $\div$ time.)

These units are used to measure the rate of flow or passage of units of electricity per second, just as the rate of flow of water or air is measured in units like cubic feet per second. The current in amperes is, according to Ohm's law, equal to the electromotive force in volts divided by the resistance in ohms; or, according to Joule's law, to the power in watts divided by the volts; or to the square root of the quotient of the watts divided by the ohms. These apply to direct currents without counter-electromotive forces; they apply to alternating currents also when there is no reactance in the circuit (caused by inductance or capacity), in which case they refer to the effective current. In any alternating current circuit with reactance the current in amperes is equal to the electromotive force in volts divided by the impedance in ohms. An ampere is also equal to a passage of one coulomb per second.

The unit universally used is the **ampere**, by which is here meant the **international ampere** of the International Congress of 1893 at Chicago, defined as equal to $\frac{1}{10}$ of the C.G.S. electromagnetic unit of current; it was made legal in this country by Congress in 1894. For practical purposes it is defined by that congress as the current which (under specified conditions) deposits 0.001 118 gram of silver per second.† The ampere is, however, preferably determined from the ohm and the voltage of a standard cell. Owing to the slight discrepancy in the units of current, electromotive force, resistance, and Ohm's law, the National Bureau of Standards has selected two of these as the fundamental units, namely those of resistance and electromotive force established by the International Congress and legalized in this country, and from these the ampere is derived, thus bringing all three into agreement with Ohm's law. Individual Clark standard cells agree with each other to within at least 2 parts in 10 000., and by the use of carefully purified materials this agreement can be still closer, while different determinations of the electro-chemical equivalent of silver differ by considerably larger amounts, unless repeated under perfectly definite conditions and made with great care. The Reichsanstalt measured the electromotive force of the Clark cell in terms of the ohm and the ampere based on the silver voltameter, but obtained a slightly different value for this cell from that defined by the International Congress; hence the ampere of the Reichsanstalt, which is in agreement with the volt and ohm there used, is slightly different from the ampere used in this country, which is based on the international volt and ohm, although both these amperes were originally intended to be the same. But this discrepancy, which is only about 8 hundredths of one percent, is quite negligible in ordinary practice. According to Weston the concrete volt, ampere, and ohm as defined by the Chicago Congress are in agreement with each other to within one part in 1000.

In some of the relations with other units, such as the absolute, the magnetic, the energy units, etc., the value of the international ampere as above defined is in the following tables assumed to be equal to the theoretical value, namely $\frac{1}{10}$ of the electromagnetic C.G.S. unit, which value is sometimes called the **true ampere**.

The **electromagnetic C.G.S. unit** (or absolute unit) is that current which, flowing in the circumference of a circle of one centimeter radius, will, for every centimeter length of circumference, exert in air a force of one dyne on a unit magnetic pole placed at the center; one whole circumference therefore exerts a force of 2π dynes on that pole. Or under the same conditions, every centimeter of the circumference will in air produce at the center a magnetic field of one unit density (one gauss), that is, one unit of magnetic flux (one maxwell) per square centimeter.

The **electrostatic C.G.S. unit** (or absolute unit) is the current which flows when one electrostatic C.G.S. unit of quantity passes per second.

† This is the value used in calibrating the Weston amperemeters.

ELECTRICAL CURRENT.

** Accepted by the National Bureau of Standards.

* Checked by Dr. Frank A. Wolff, Jr., Asst. Phys. National Bureau of Standards.

Aprx. means within 2%. By "ampere" is meant the international ampere, assumed to be equal to the international volt divided by the international ohm, unless otherwise stated. v is the velocity of light.

	Logarithm
1 CGS unit (elst) = 1 abstatampere	0.000 0000
" = $10^7/v$ microampere. About $\frac{1}{3} \div 1\ 000$	4.522 8787
" = $10/v$ ampere. About $\frac{1}{3} \times 10^{-9}$	10.522 8787
" = $1/v$ CGS unit (elmg). About $\frac{1}{3} \times 10^{-10}$...	11.522 8787
1 abstatampere = 1 CGS unit (elst)	0.000 0000
1 microampere = $v/10^7$ CGS units (elst). About 3 000..	3.477 1213
" = 0.000 001 ampere.....	6.000 0000
1 milliampere = $v/10\ 000$ CGS units (elst). About 3 000 000.	6.477 1213
" = 0.001 ampere.....	3.000 0000
" = 0.0001 CGS unit (elmg).....	4.000 0000
1 ampere [A, a] = $v/10$ CGS units (elst). About 3×10^9 .	9.477 1213
" = 1000. milliamperes.....	3.000 0000
" = 0.999 198** ampere of Reichsanstalt†.....	1.999 6516
" = 0.1 CGS unit (elmg).....	1.000 0000
1 international ampere = 1 ampere, which see above.....	0.000 0000
1 true ampere = 0.1 CGS unit (elmg).....	1.000 0000
1 ampere of Reichsanstalt = 1.000 803** amperes†.....	0.000 3484
1 ampere of Nat. Bureau of Standards = 1 volt $\div$ 1 ohm.	
1 CGS unit (elmg) = v CGS units (elst). About 3×10^9	10.477 1213
" = 10. amperes	1.000 0000
" = 1 absampere.....	0.000 0000
1 absampere = 1 CGS unit (elmg).....	0.000 0000
1 kiloampere = 1 000. amperes	3.000 0000
" = 100. CGS units (elmg).....	2.000 0000
1 absolute unit = 1 CGS unit, either elst or elmg.....	0.000 0000

The relations to other measures are as follows:†

Amperes = volts $\div$ ohms.

" = coulombs $\div$ seconds.

" = watts $\div$ volts.

" = $1\ 000 \times$ kilowatts $\div$ volts.

" = $\sqrt{(\text{watts} \div \text{ohms})}$.

" = joules $\div$ (volts $\times$ second).

" = $\sqrt{[\text{joules} \div (\text{ohms} \times \text{seconds})]}$.

Rate of change of amperes per second:

= induced volts $\div$ henrys.

= induced volts $\div$ (ohms $\times$ time constant in seconds).

Final amperes:

= applied volts $\times$ time constant in seconds $\div$ henrys.

= joules of kinetic energy of the current $\times$ ohms $\times 2 \div$ (henrys $\times$ applied volts).

= $\sqrt{(\text{joules of kinetic energy of the current} \times 2 \div \text{henrys})}$.

= joules of kinetic energy of the current $\times 2 \div$ (applied volts $\times$ time constant in seconds).

= $\sqrt{[\text{joules of kinetic energy of the current} \times 2 \div (\text{ohms} \times \text{time constant in seconds})]}$.

† See explanatory notes above.

† Treatises on alternating currents should be consulted for the limiting conditions under which these relations apply to alternating or other periodically varying quantities

When the flux is due only to the current, as in self-induction, and when there is no magnetic leakage:

Final amperes:

- = (maxwells $\times$ number of turns) $\div$ (henrys $\times 10^8$).
- = (maxwells $\times$ number of turns) $\div$ (time constant in seconds $\times$ ohms $\times 10^3$).
- = ergs of kinetic energy of the current $\times 20 \div$ (maxwells $\times$ no. of turns).
- = joules of kinetic energy of the current $\times 2 \times 10^3 \div$ (maxwells $\times$ number of turns).

When there is magnetic leakage, substitute in the above for the quantity "maxwells $\times$ number of turns," the mean flux turns, that is the "mean maxwells $\times$ number of turns." Thus:

Final amperes:

- = (mean maxwells $\times$ number of turns) $\div$ (henrys of self-induction $\times 10^8$).

When the flux is from an external source, and independent of the current as in mutual induction, and when there is no magnetic leakage:

Final amperes:

- = ergs of kinetic energy of the current $\times 10 \div$ (maxwells $\times$ no. of turns).
- = joules of kinetic energy of the current $\times 10^3 \div$ (maxwells $\times$ no. of turns)

When there is magnetic leakage, make the same substitution as described above.

Final amperes in primary:

- = mean maxwells through secondary $\times$ secondary turns $\div$ (henrys of mutual induction $\times 10^8$).

For alternating-current circuits†:

Amperes:

- = watts $\div$ (volts $\times \cos \phi$ ‡).
- = $\sqrt{\text{watts} \div (\text{ohms} \times \cos \phi)}$.
- = $\sqrt{[\text{applied volts}^2 - \text{induced volts}^2] \div \text{ohms resistance}}$.
- = farads $\times$ volts $\times$ frequency $\times 6.283\ 19\ \S$.
- = microfarads $\times$ volts $\times$ frequency $\times 6.283\ 19\ \S \div 1\ 000\ 000$.
- = induced volts $\div$ (henrys $\times$ frequency $\times 6.283\ 19\ \S$).
- = induced volts $\div$ (time constant in seconds $\times$ ohms resistance $\times$ frequency $\times 6.283\ 19\ \S$).
- = applied volts $\div \sqrt{[(\text{henrys} \times \text{frequency} \times 6.283\ 19\ \S)^2 + (\text{ohms res.})^2]}$.

CURRENT DENSITY. (Current $\div$ surface.)

These units are used to measure the current flowing through a unit cross-section of a wire or other conductor; or the amount of current flowing into or out of a unit surface of an electrode in an electrolyte.

Aprx. means within 2%.

1 ampere per sq. meter:

	Logarithm
= 0.092 903 4 ampere per sq. foot. Aprx. $1\frac{1}{12} \div 10$	2 968 0317
= 0.01 ampere per sq. decimeter.	2.000 0000
= 0.000 645 163 ampere per sq. inch. Aprx. $\frac{7}{11} \div 1\ 000$	4.809 6692

1 ampere per sq. foot:

= 10.763 87 amperes per sq. meter. Aprx. $12\frac{1}{11} \times 10$	1 031 9683
= 0.107 638 7 ampere per sq. decimeter. Aprx. $12\frac{1}{11} \div 100$	1.031 9683
= 0.006 944 44 ampere per sq. inch. Aprx. $\frac{7}{1000}$	3.841 6375

1 ampere per sq. decimeter:

= 100 amperes per sq. meter.	2.000 0000
= 9.290 34 amperes per sq. foot. Aprx. $11\frac{1}{12} \times 10$	0 968 0317
= 0.064 5163 ampere per sq. inch. Aprx. $\frac{7}{11} \div 10$	2.809 6692

† Treatises on alternating currents should be consulted for the limiting conditions under which these relations apply to alternating or other periodically varying quantities.

‡ ϕ is the phase difference in degrees.

§ Or 2π . Aprx. $\frac{5}{8} \times 10$. Log 0.798 1799.

Logarithm

1 ampere per sq. inch:

= 1 550.00 amperes per sq. meter. Aprx. $1\frac{1}{4} \times 1\,000$	3.190 3308
= 144 amperes per sq. foot. Aprx. $\frac{1}{4} \times 1\,000$	2.158 3625
= 15.500 0 amperes per sq. decimeter. Aprx. $1\frac{1}{4} \times 10$..	1.190 3308
= 0.785 398 ampere per circular inch. Aprx. $\frac{8}{10}$	1.895 0899
= 0.155 000 ampere per sq. centimeter. Aprx. $\frac{2}{13}$	1.190 3308
= 0.121 736 ampere per circular cm. Aprx. $12 \div 100$	1.085 4207

1 ampere per circular inch:

= 1.273 24 amperes per sq. inch. Aprx. $\frac{1}{8}$	0.104 9101
= 0.197 352 ampere per sq. centimeter. Aprx. $\frac{2}{10}$	1.295 2409
= 0.155 000 ampere per circular cm. Aprx. $\frac{2}{13}$	1.190 3308

1 ampere per sq. centimeter:

= 929.034 amperes per sq. foot. Aprx. $1\frac{1}{12} \times 1\,000$	2.968 0317
= 100 amperes per sq. decimeter	2.000 0000
= 6.451 63 amperes per sq. inch. Aprx. $6\frac{1}{2}$	0.809 6692
= 5.067 09 amperes per circular inch. Aprx. 5	0.704 7591
= 0.785 398 ampere per circular centimeter. Aprx. $\frac{8}{10}$	1.895 0899

1 ampere per circular centimeter:

= 8.214 47 amperes per sq. inch. Aprx. $\frac{5}{6} \times 10$	0.914 5793
= 6.451 63 amperes per circular inch. Aprx. $1\frac{3}{2}$	0.809 6692
= 1.273 24 amperes per sq. centimeter. Aprx. $\frac{1}{8}$	0.104 9101

1 ampere per sq. millimeter:

= 0.785 398 ampere per circular mm. Aprx. $\frac{8}{10}$	1.895 0899
= 0.000 645 163 ampere per sq. mil. Aprx. $\frac{7}{11} \div 1\,000$..	4.809 6692
= 0.000 506 709 ampere per circular mil. Aprx. $\frac{1}{2} \div 1\,000$.	4.704 7591

1 ampere per circular millimeter:

= 1.273 24 amperes per sq. millimeter. Aprx. $\frac{1}{8}$	0.104 9101
= 0.000 821 447 ampere per sq. mil. Aprx. $\frac{1}{12} \div 100$	4.914 5793
= 0.000 645 163 ampere per circular mil. Aprx. $\frac{7}{11} \div 1\,000$.	4.809 6692

1 ampere per sq. mil:

= 1 550.00 amperes per sq. millimeter. Aprx. $1\frac{1}{4} \times 1\,000$..	3.190 3308
= 1 217.36 amperes per circular mm. Aprx. $\frac{9}{5} \times 1\,000$...	3.085 4207
= 0.785 398 ampere per circular mil. Aprx. $\frac{8}{10}$	1.895 0899

1 ampere per circular mil:

= 1 973.52 amperes per sq. millimeter. Aprx. 2 000	3.295 2409
= 1 550.00 amperes per circular mm. Aprx. $1\frac{1}{4} \times 1\,000$...	3.190 3308
= 1.273 24 amperes per sq. mil. Aprx. $\frac{1}{8}$	0.104 9101

ELECTRICAL QUANTITY [Q, q]; CHARGE. (Current × time; capacity × electromotive force.)

These units are used to measure the amount of electricity as such, just as a quantity of matter might be measured in the number of units called molecules, which it contains. The number of units of electricity in a given quantity of electricity is the same whether or not it is flowing in the form of a current, or whether or not it is subjected to an electrical pressure, just as the number of molecules in a given weight of air is the same whether or not it is in motion, as in a wind, or whether or not it is under pressure, as in compressed air. The quantity of electricity in coulombs is equal to the current in amperes multiplied by the time in seconds; or to the energy in joules divided by the voltage; or to voltage multiplied by the capacity of a condenser in farads.

The unit generally used is the **coulomb**, by which is here meant the **international coulomb** of the International Congress of 1893 at Chicago, defined as "the quantity of electricity transferred by a current of one international ampere in one second." It was made legal in this country by Congress in 1894, and is accepted by the National Bureau of Standards. For practical purposes it is that quantity which will deposit 0.001 118 gram of silver in a silver voltameter. In some of the relations with other units, such as the absolute, the energy units, etc., the above value is in the following tables assumed to be equal to the theoretical value, namely $\frac{1}{10}$ the electromagnetic C.G.S. unit. Another unit frequently used, especially with batteries and in electrochemistry, is the **ampere-**

hour; it is the quantity of electricity transferred by a current of one ampere in one hour.

The **electromagnetic C.G.S. unit** (or absolute unit) is the quantity of electricity transferred by one electromagnetic C.G.S. unit of current in one second. The **electrostatic C.G.S. unit** (or absolute unit) is that quantity of electricity which in air exerts a force of one dyne on an equal quantity one centimeter distant.

ELECTRICAL QUANTITY; CHARGE.

Aprx. means within 2%. By "coulomb" is meant the international coulomb. v is the velocity of light.

	Logarithm
1 CGS unit [elst]:	
= 1 abstatcoulomb.....	0 000 0000
= $10^7/v$ microcoulomb. About $\frac{1}{3} + 1\ 000$	4 522 8787
= $10/v$ coulomb. About $\frac{1}{3} \times 10^{-9}$	10.522 8787
= $1/v$ CGS unit (elmg). About $\frac{1}{3} \times 10^{-10}$	11.522 8787
= $1 + (360\ v)$ ampere-hour. About 9.259×10^{-14}	14.966 5762
1 abstatcoulomb = 1 CGS unit (elst)	0.000 0000
1 microcoulomb:	
= $v \times 0.000\ 000\ 1$ CGS units (elst). About 3 000.....	3.477 1213
= 0.000 001 coulomb.....	6.000 0000
= 0.000 000 1 CGS unit (elmg).....	7.000 0000
= $2.777\ 78 \times 10^{-10}$ ampere-hour. Aprx. $\frac{11}{4} \times 10^{-10}$	10.443 6975
1 coulomb [C, c]:	
= $v/10$ CGS units (elst). About 3 000 000 000....	9.477 1213
= 1 000 000. microcoulombs.....	6.000 0000
= 0.1 CGS unit (elmg).....	1.000 0000
= 0.000 277 778 ampere-hour. Aprx. $\frac{11}{4} + 10\ 000$	4.443 6975
1 international coulomb = 1 coulomb, which see above.	
1 true coulomb = 0.1 CGS unit (elmg).	1.000 0000
1 ampere-second = 1 coulomb, which see above.	
1 CGS unit (elmg):	
= 1 abscoulomb.....	0 000 0000
= v CGS units (elst). About 3×10^{10}	10.447 1213
= 10 coulombs.....	1.000 0000
= 0.002 777 78 ampere-hour. Aprx. $\frac{11}{4} + 1\ 000$	3.443 6975
1 abscoulomb = 1 CGS unit (elmg).	0.000 0000
1 ampere-hour [ah]:	
= $v \times 360$. CGS units (elst). About 1.08×10^{13}	13.033 4238
= 3600. coulombs.....	3.556 3025
= 360. CGS units (elmg).....	2.556 3025
1 absolute unit = 1 CGS unit, either elst. or elmg.	0.000 0000

The relations to other measures are as follows:†

Coulombs = amperes $\times$ seconds.

" = amperes $\times$ hours $\times$ 3 600.

" = volts $\times$ seconds $\div$ ohms.

" = watts $\times$ seconds $\div$ volts.

" = $\sqrt{(\text{watts} \times \text{seconds}^2 + \text{ohms})}$.

" = joules $\div$ volts.

" = $\sqrt{(\text{joules} \times \text{seconds} \div \text{ohms})}$.

" = farads $\times$ volts.

" = microfarads $\times$ volts $\div$ 1 000 000.

Ampere-hours = coulombs $\div$ 3 600.

" = amperes $\times$ hours.

" = volts $\times$ hours $\div$ ohms.

" = watts $\times$ hours $\div$ volts.

" = $\sqrt{(\text{watts} \times \text{hours}^2 + \text{ohms})}$.

" = joules $\div$ (volts $\times$ 3 600).

" = $\sqrt{[\text{joules} \times \text{hours} \div (\text{ohms} \times 3\ 600)]}$.

Microcoulombs = microfarads $\times$ volts.

† Treatises on alternating currents should be consulted for the limiting conditions under which these relations apply to alternating or other periodically varying quantities.

ELECTRICAL CAPACITY [C, c]. (Quantity ÷ electromotive force.)

These units are used to measure the ability of a body (like a condenser) to hold charges of electricity (measured in coulombs) under electrical stress, pressure, or potential (measured in volts). The capacity of a condenser is greater the greater the charge in coulombs that it will hold for the same pressure in volts, or the less the pressure in volts required for the same charge. The capacity in farads is equal to the charge in coulombs divided by the electromotive force in volts. In some respects an electrical capacity is analogous to the capacity of a closed vessel to hold air under pressure, the greater the pressure the greater the quantity of air, yet the capacity of the vessel remains the same and could be measured in terms of the air and its pressure.

The unit universally used is the **microfarad** or millionth of a farad; by farad is here meant the **international farad** of the International Congress of 1893 at Chicago, defined as equal to one international coulomb divided by one international volt. It was made legal in this country by Congress in 1894, and is accepted by the National Bureau of Standards. As the farad is an inconveniently large unit, never occurring in practice, the microfarad is generally used. The **electromagnetic C.G.S. unit** (or absolute unit) is the capacity of a condenser which when charged at one C.G.S. unit of potential will hold one C.G.S. unit of quantity. The **electrostatic C.G.S. unit** (or absolute unit) is similarly defined with respect to the electrostatic units of potential and quantity.

By "farad" is meant the international farad. v is the velocity of light.

	Logarithm
1 CGS unit [elst] = 1 abstafarad.....	0.000 0000
" = $10^{15}/v^2$ microfarad. About $\frac{1}{9} \times 10^{-5}$	6.045 7575
" = $10^9/v^2$ farad. About $\frac{1}{9} \times 10^{-11}$	12.045 7575
" = $1/v^2$ CGS unit (elmg). About $\frac{1}{9} \times 10^{-20}$	21.045 7575
1 abstafarad = 1 CGS unit (elst).....	0.000 0000
1 microfarad = $v^2 \times 10^{-15}$ CGS units (elst). About 9×10^5	5.954 2425
" = 1 microcoulomb ÷ 1 volt.....	0.000 0000
" = 0.000 001 farad.....	6.000 0000
" = 10^{-15} CGS unit (elmg).....	15.000 0000
1 farad [F] = $v^2 \times 10^{-9}$ CGS units (elst). About 9×10^{11}	11.954 2425
" = 1 000 000. microfarads.....	6.000 0000
" = 10^{-9} CGS unit (elmg).....	9.000 0000
1 international farad = 1 farad, which see above.....	0.000 0000
1 CGS unit (elmg) = v^2 CGS units (elst). About 9×10^{20}	20.954 2425
" = 10^{15} microfarads.....	15.000 0000
" = 10^9 farads.....	9.000 0000
" = 1 abfarad.....	0.000 0000
1 abfarad = 1 CGS unit (elmg).....	0.000 0000
1 absolute unit = 1 CGS unit, either elmg or elst.....	0.000 0000

The relations to other measures are as follows: †

Farads = coulombs ÷ volts.

" = joules of stored energy ÷ 2 ÷ volts².

Microfarads = coulombs ÷ 1 000 000. ÷ volts.

" = microcoulombs ÷ volts.

" = joules of stored energy ÷ 2 000 000. ÷ volts².

For alternating-current circuits: †

Farads = amperes ÷ (volts × frequency × 6.283 19 †).

" = -1 ÷ (ohms reactance × frequency × 6.283 19 †).

Microfarads = amperes ÷ 1 000 000 ÷ (volts × frequency × 6.283 19 †).

" = 1 000 000. ÷ (ohms reactance × frequency × 6.283 19 †).

† Treatises on alternating currents should be consulted for the limiting conditions under which these relations apply to alternating or other periodically varying quantities.

‡ Or 2π . Aprx. $\frac{5}{8} \times 10$. Log 0.798 1799.

$$1 \text{ cm} = 1.111 \times 10^{-12} \text{ farads}$$

INDUCTANCE [L , l]; **COEFFICIENT of SELF- or MUTUAL INDUCTION.** ($\text{E.m.f.} \div (\text{current} \div \text{time})$); **resistance** $\times$ **time**; **number of turns** $\times$ **flux** $\div$ **current**; **kinetic energy** $\div$ **square of current.**)

These units are used to measure the intensity of that property by virtue of which an electromotive force is produced by changes of current in a neighboring circuit (as in a transformer) or by changes of current in the circuit itself; in the former case the phenomenon is called mutual induction, and in the latter self-induction. An electric current has a property analogous in some respects to the inertia of a heavy moving body; a current resists momentarily any change in its strength, just as a heavy moving body resists any change in its velocity. When a current is started, it encounters for a short time (see time-constant below) a counter-electromotive force in its own circuit due either to itself (self-induction) or to a current in the opposite direction which it is inducing in a neighboring circuit (mutual induction). Similarly, if stopped it tends to prolong itself either in its own circuit or (by induction) in a neighboring circuit; the quicker the change the greater this tendency. This property is due to the inductance.

The term **induction** in electrodynamics applies broadly to the general phenomenon of the generation of an electromotive force (which may or may not produce a current) by magnetic flux, whether it be that of a magnet or that surrounding a current. The terms **self** and **mutual induction** apply to the special cases of this phenomenon when the induction is produced by a current in its own circuit or in a neighboring circuit respectively, there being no mechanical motion. The terms **coefficient of self** or **coefficient of mutual induction** apply to the numerical value of the intensity of this phenomenon, by which it is measured; the terms **self-inductance** and **mutual inductance** are now more generally used instead. The term **inductance** applies to both of these coefficients, and is therefore the measure of self or mutual induction. The **inductance factor** is the ratio of the wattless volt amperes to the total volt amperes; or the ratio of the wattless component of the current or e.m.f. to the total current or e.m.f.

The inductance depends for its value on the geometric conditions of the circuit, and varies with the size and shape of the circuit or of a coil, with the square of the number of turns of a coil, with the distance between the wires, etc.; it also varies according to an irregular law with the presence of iron or other magnetic material. An inductance, in henrys, is measured by and is equal to the electromotive force induced, in volts, divided by the rate of change of current in amperes per second, which causes it; it is also equal in henrys to twice the kinetic (magnetic) energy of the circuit in joules divided by the square of the final current in amperes; a coefficient of self-induction in henrys is also equal to the resistance of the circuit in ohms multiplied by its time-constant (see below) in seconds. The inductance of any particular circuit is also the constant relation of the product of the magnetic flux and the turns, to the current producing the flux.

In the C.G.S. system of units, on which the practical unit is based, this measure happens to be of the same kind as a length; this is a consequence of what is called a "suppressed factor" in the dimensional formula, and as it is misleading and answers no useful purpose, the coincidence should not be given any importance. While it is not incorrect to express inductances in centimeters, it misleads and is not good practice. The electromotive force produced by inductance is generated precisely as in dynamos by the cutting of magnetic flux or lines of force and at the rate of 10^8 such lines (maxwells) per second for each volt, the magnetic flux in inductance being that produced by the current, and is proportional in amount to the change in the current strength. In the case of dynamos the wire moves and the flux is at rest, while in inductance the wire is at rest and the flux moves.

The unit now most generally used is the **henry**. By henry is here meant that of the International Congress of 1893 at Chicago, defined as the induction in a circuit when the electromotive force induced in this circuit is one

international volt, while the inducing current varies at the rate of one international ampere per second. It was made legal in this country by Congress in 1894, and is accepted by the National Bureau of Standards. In some of the relations in these tables, this value is assumed to be equal to 10^9 C.G.S. electromagnetic units of inductance. This unit was formerly, and for some years officially, called a "quadrant." If the self-inductance of a given circuit (usually a coil) is one henry, it means that the magnetic lines of force corresponding in that circuit to one ampere will form 10^8 linkages of unit magnetic lines of force (maxwells) with that circuit. The unit called **sec-ohm** was at one time used, as in self-induction the inductance is equal to the product of the resistance in ohms, and the time-constant of the circuit in seconds.

The **electromagnetic C.G.S. unit** (or absolute unit) is that induction which will induce one C.G.S. unit of electromotive force by a change of current at the rate of one C.G.S. unit of current per second. It happens to be numerically equal to 1 centimeter of length and is sometimes so represented. The **electrostatic C.G.S. unit** (or absolute unit) is similarly defined with respect to the electrostatic units of electromotive force and current.

INDUCTANCE.

v is the velocity of light.	Logarithm
1 CGS unit (elmg) = 1 centimeter.....	0.000 0000
" = 0.001 microhenry.....	3.000 0000
" = 10^{-9} henry.....	9.000 0000
" = $1/v^2$ CGS unit (elst). About $\frac{1}{9} \times 10^{-20}$..	21.045 7575
1 centimeter inductance = 1 CGS unit (elmg).....	0.000 0000
1 microhenry = 1 000. CGS units (elmg).....	3.000 0000
" = 0.000 001 henry.....	6.000 0000
1 millihenry = 0.001 henry.....	3.000 0000
1 henry [H] = 10^9 CGS units (elmg).....	9.000 0000
" = 10 000. kilometers, or 1 earth's quadrant.....	4.000 0000
" = $10^9/v^2$ CGS unit (elst). About $\frac{1}{9} \times 10^{-11}$	12.045 7575
1 quadrant = 1 henry.....	0.000 0000
1 quad = 1 quadrant or henry.....	0.000 0000
1 sec-ohm = 1 henry.....	0.000 0000
1 CGS unit (elst) = v^2 CGS units (elmg). About 9×10^{20} ..	20.954 2425
" = v^2 centimeters. About 9×10^{20} ..	20.954 2425
" = $v^2 \times 10^{-9}$ henrys. About 9×10^{11}	11.954 2425

The relations to other measures are as follows:†

- Henrys** = induced volts ÷ rate of change of amperes per second.
 " = time constant in seconds × ohms.
 " = time constant in seconds × applied volts ÷ final amperes.
 " = joules of kinetic energy of the current × 2 ÷ final amperes².
 " = joules of kinetic energy of the current × ohms² × 2 ÷ applied volts².

When the flux is due only to the current, as in self-induction, and when there is no magnetic leakage:

Henrys of self-induction:

- = (maxwells × number of turns²) ÷ (ampere-turns × 10^8).
 = (maxwells × number of turns) ÷ (final amperes × 10^8).
 = (number of turns × 0.000 1)² × 1.256 64 † ÷ oersteds.

When there is magnetic leakage, substitute in the above for the quantity "maxwells × number of turns," the *mean* flux turns, that is, the "mean maxwells × number of turns." Thus:

Henrys of self-induction:

- = (mean maxwells × number of turns) ÷ (final amperes × 10^8).

When the flux is from an external source and independent of the current, as in mutual induction, and when there is magnetic leakage:

Henrys of mutual induction:

- = (mean maxwells through the secondary × secondary turns) ÷ (final amperes in primary × 10^8).

† Treatises on alternating currents should be consulted for the limiting conditions under which these relations apply to alternating or other periodically varying quantities.

† Or $4\pi + 10$. Aprx. 10%. Log 0.099 2099.

For alternating current circuits:†

Henrys = induced volts ÷ (amperes × frequency × 6.283 19 †).

" = ohms reactance ÷ (frequency × 6.283 19 †).

" = $\sqrt{(\text{ohms impedance}^2 - \text{ohms resistance}^2)} \div \text{frequency} \times 6.283\ 19\ \dagger$.

" = $\sqrt{[(\text{applied volts} \div \text{amperes})^2 - \text{ohms resistance}^2]} \div \text{frequency} \times 6.283\ 19\ \dagger$.

Inductance factor:

= wattless component of current or e.m.f. ÷ total current or e.m.f.

= $\sqrt{(1 - \text{power factor}^2)}$.

TIME-CONSTANT (of inductive circuits). (Inductance ÷ resistance; time.)

When a current is started in a circuit containing inductance of the kind called self-induction, as is the case for instance in coils, particularly if they have many turns and iron cores, the current will not reach its full value instantly, but owing to the self-induction it will at first be opposed by a counter-electromotive force due to the inductance; this opposition will grow less and less until the current has reached its full strength. It is similar to what takes place when a heavy weight like a street car is started to move; its inertia will at first oppose the moving force, but this opposition will grow less and less as the speed increases until the full, constant speed is attained, and the inertia will then offer no further opposition.

It is sometimes of importance to know how long it takes before the current has reached its ultimate value, but theoretically it takes an infinite time, and therefore it is usual to state the time that it takes the current to rise to a certain definite fractional part of its full value, namely nearly $\frac{2}{3}$ (the exact figure is given below), and this time is called the "time-constant" of that circuit. This time in seconds (often a very small fraction of a second) is equal to the self-induction in henrys divided by the resistance in ohms; or instead of the ohms one may of course use the applied volts divided by the final steady current in amperes. This time-constant is therefore greater the greater the self-induction and the less the resistance. It gives more information about a circuit than the mere inductance does, as it includes the resistance; the self-inductance of a coil, for instance, is the same whether the wire is made of copper or of a high resisting metal, but the time-constant is less in the latter case.

The exact fractional part of the full value of the current, above referred to, is $(e - 1) \div e$, in which e is the base of the Naperian logarithms. Numerically this is equal to 63.212%, or nearly $\frac{2}{3}$.

The unit in which time-constants are always given is the **second**, hence there are no reduction factors. The most important relations to other measures are as follows:

Time-constant in seconds = henrys ÷ ohms resistance.

" = henrys × final amperes ÷ applied volts.

For further relations see those for henrys under inductance, and divide them by the ohms resistance.

† Treatises on alternating currents should be consulted for the limiting conditions under which these relations apply to alternating or other periodically varying quantities.

‡ Or 2π . Aprx. $\frac{5}{8} \times 10$. Log 0.798 1799.

FREQUENCY; PERIODICITY; PERIOD; ALTERNATIONS. ($1 \div \text{time}$; time.)

Frequency or **periodicity** is the number of recurrences or cycles of some periodic or wave phenomenon or oscillation during a given time which is always understood to be a second unless otherwise stated; the frequency always refers to the number of *complete* cycles. The **number of alternations**, however, refers to the number of changes of the direction or to the reversals, and therefore refers to half-waves, and is always equal to double the frequency, if the time is the same. The **period** is the time of one complete wave or oscillation and is therefore the reciprocal of the frequency. The term "frequency" is the one most generally used, and always refers to a second; the term "number of alterations" is preferred by some, and when it refers to electric currents the time is usually a minute; the term "period" is used comparatively rarely as a measure, its use being generally limited to scientific discussions; the unit is generally the second.

In mathematical discussions of electric alternating-current problems the frequency is often replaced by an angular velocity, generally represented by ω and measured in terms of radians per second (see under Angular Velocities above). Then $\omega = 2\pi n$, in which ω is in radians per second and n is the true frequency in cycles per second, a cycle being here considered the same thing as a complete revolution.

The frequency is also equal to the velocity of propagation divided by the wave-length. The wave-lengths are therefore measured in units of length, but when the velocity for a class of waves is a constant (as those of light or the electromagnetic waves), the wave-lengths may also be indicated in units of time, in which case a wave-length becomes equal to the period of the wave. Wave-length should not be confounded with the **amplitude**, which measures the intensity of the wave and has nothing to do with the frequency, period, or wave-length.

If n is the **frequency** per second [ω], then:
 the period in seconds $= 1/n$;
 the number of alternations per minute $= 120n$.

If n is the **number of alternations** per minute, then:
 the frequency per second $= n/120$;
 the period in seconds $= 120/n$.

If n is the **period** in seconds, then:
 the frequency per second $= 1/n$;
 the number of alternations per minute $= 120n$.

If n is the **frequency** in cycles per second, and ω the **angular velocity** in radians per second, and if a cycle is represented by one complete revolution, then:

$$\omega = 2\pi n; \text{ or}$$

$$n = 0.159\ 155\omega; \text{ and}$$

$$\omega = 6.283\ 19n.$$

An **electrical degree** is the 360th part of one complete cycle.

For the relations of frequency to other measures see those relations between other measures which involve the frequency, chiefly under farads and henrys.

KINETIC ENERGY of a CURRENT in a CIRCUIT [W]. (Inductance $\times$ current²; power $\times$ time-constant; energy.)

As was explained above under "Time-constant," it takes an appreciable time to start a current in a circuit having inductance. During this interval of time energy is being stored up in the circuit, which is given back again, usually in the form of a spark, when the current is stopped; this is called the kinetic energy of the current in the circuit. It has an analogy in the storing of energy in a heavy body like a street car when it is started to move, which energy is given back again when the body is stopped.

This kinetic energy is greater the greater the self-induction and the greater the current. It is equal in joules to half the product of the self-inductance in henrys and the square of the current in amperes at any instant, and therefore also of the amperes of the final steady current. Similarly in mechanics, this kinetic energy is equal to half the product of the mass and the square of the velocity at any instant, and therefore also of the final steady velocity. This energy is stored in the form of magnetic energy, and during that time it is potential energy; it remains stored as long as the current continues, and is given out again when the current ceases. In a transformer it is the kinetic energy of the primary circuit which is transmitted to and is led out by the secondary. The practical unit is the joule, and the C.G.S. unit is the erg.

The chief relations to other measures are as follows:

Joules of kinetic energy of the current = henrys $\times$ final amperes² $\div$ 2.

Ergs of kinetic energy of the current = henrys $\times$ final amperes² $\times 5 \times 10^6$.

For further relations see under units of Electrical Energy, below.

ELECTRICAL ENERGY OR WORK [W]. (Quantity $\times$ electromotive force; current² $\times$ resistance $\times$ time; power $\times$ time; power $\div$ frequency.)

The units of electrical energy are all convertible directly into units of other kinds of energy, as energy is the one quantity common to all the systems of units. The electrical and absolute units have therefore been included with the mechanical, thermal, and other units in the general table of all the units of Energy (p. 74); the present table is limited to a few specific values and to some relations between the electrical unit of energy and other electrical units.

The energy in joules delivered to a circuit is equal to the electromotive force in volts multiplied either by the quantity of electricity in coulombs, or by the product of the current in amperes and the time in seconds. These apply to direct currents; in alternating-current calculations involving energy, the power and not the work done is generally the important consideration; the energy of alternating currents of any wave form delivered per cycle, in joules, is equal to the power in mean watts divided by the frequency. For the energy stored in a current see the preceding section on Kinetic Energy.

The unit universally used is the joule, by which is here meant the joule of the International Congress of 1893 in Chicago, defined as equal to 10⁷ C.G.S. units of work (ergs) and represented sufficiently well for practical use by the energy expended in one second by an international ampere in an international ohm; in the relations in these tables this defined value is used. It was made legal in this country by Congress in 1894 and is accepted by the National Bureau of Standards. Sometimes the ampere-hour is used as the unit of electrical quantity, in which case the corresponding unit of energy becomes the volt-ampere-hour, usually called the watt-hour; the kilowatt-hour (= 1000. watt-hours) is also common. The electromagnetic C.G.S. unit (or absolute unit) is the erg, defined as the work of one dyne acting through one centimeter. The electrostatic C.G.S. unit (or absolute unit) is this same erg.

ELECTRICAL ENERGY.

Aprx. means within 2%.

	Logarithm
1 CGS unit (elmg) = 1 erg.	0.000 0000
1 CGS unit (elst) = 1 erg.	0.000 0000
1 absolute unit = 1 erg.	0 000 0000
1 erg = 1 CGS unit (elmg).	0.000 0000
" = 1 CGS unit (elst).	0.000 0000
" = 10^{-7} joule	7.000 0000
1 microjoule = 10. ergs.	1.000 0000
1 joule [J] = 10 000 000. ergs.	7.000 0000
" = 0.000 277 778 watt-hour. Aprx. $\frac{3}{41} + 1$ 000.	4.443 6975
1 kilojoule = 1 000. joules.	3.000 0000
1 watt-hour = 3 600. joules.	3.558 3025
" = 3.6 kilojoules.	0.558 3025
1 kilowatt-hour = 3 600 000. joules.	6.558 3025
" = 1 000. watt-hours.	3.000 0000

For further conversion factors see table of units of Energy, page 74.

The relations to other measures are as follows: †

Joules = volts $\times$ coulombs.

" = volts $\times$ amperes $\times$ seconds.

" = volts² $\times$ seconds $\div$ ohms.

" = amperes² $\times$ ohms $\times$ seconds.

" = ohms $\times$ coulombs² $\div$ seconds.

" = watts $\times$ seconds.

Joules of stored energy = farads $\times$ volts² $\div$ 2.

" = microfarads $\times$ volts² $\div$ 2 000 000.

Ergs of stored energy = microfarads $\times$ volts² $\times$ 5.

Joules of kinetic energy of the current:

= henrys $\times$ final amperes² $\div$ 2.

= henrys $\times$ applied volts² $\div$ (ohms² $\times$ 2).

= time-constant in seconds $\times$ ohms $\times$ final amperes² $\div$ 2.

= time-constant in seconds $\times$ final amperes $\times$ applied volts $\div$ 2.

= time-constant in seconds $\times$ applied volts² $\div$ (ohms $\times$ 2).

Ergs of kinetic energy of the current = henrys $\times$ final amperes² $\times$ 5 $\times$ 10⁸.

When the flux is due only to the current, as in self-induction, and when there is no magnetic leakage:

Joules of stored energy = maxwells $\times$ ampere-turns $\div$ (2 $\times$ 10⁸).

Ergs of stored energy = maxwells $\times$ ampere-turns $\div$ 20.

When there is magnetic leakage:

Joules of stored energy = mean maxwells $\times$ ampere-turns $\div$ 2 $\times$ 10⁸.

Ergs of stored energy = mean maxwells $\times$ ampere-turns $\div$ 20.

When the flux is from an external source, and independent of the current, as in mutual induction, and when there is no magnetic leakage:

Joules of stored energy = maxwells $\times$ ampere-turns $\div$ 10⁸.

Ergs of stored energy = maxwells $\times$ ampere-turns $\div$ 10.

When there is magnetic leakage substitute "mean maxwells" for "maxwells."

For alternating current circuits: †

Joules per cycle = watts $\div$ frequency.

= effective amperes $\times$ effective volts $\times$ cos ϕ $\div$ frequency.

† Treatises on alternating currents should be consulted for the limiting conditions under which these relations apply to alternating or other periodically varying quantities.

ELECTRICAL POWER [P]. (Current $\times$ electromotive force; energy $\div$ time; energy $\times$ frequency.)

The units of electrical power are all convertible directly into units of other kinds of power, and the electrical and absolute units have therefore been included with the mechanical, thermal, and other units in the general table of all the units of Power (p. 80). The present table is limited to a few specific values and to some relations between the electrical unit of power and other electrical units.

The power in watts is equal to the energy in joules divided by the time in seconds; this applies to both direct and alternating currents whether there is phase shifting in the latter case or not. According to Joule's law, the power in watts is also equal to the square of the current in amperes multiplied by the resistance in ohms, or to the current in amperes multiplied by the electromotive force in volts, or to the square of the electromotive force in volts divided by the resistance in ohms. These apply to direct currents; they apply to alternating currents also, but only under certain conditions, the chief one of which is that there is no reactance in the circuit and therefore no phase shifting (caused by inductance or capacity), in which case the relations refer to the effective values of the current and electromotive force. For further information treatises on alternating currents should be consulted. In any case, these relations give the true power when the result is multiplied by the power factor (see below).

The unit universally used is the **watt**, by which is here meant the watt of the International Congress of 1893, in Chicago, defined as equal to 10^7 C.G.S. units of power (erg per second) and represented sufficiently well for practical use by the work done at the rate of one joule per second; in the relations in these tables this defined value is used. It was made legal in this country by Congress in 1894, and is accepted by the National Bureau of Standards. The **kilowatt** (=1 000 watts) is also common. The **electromagnetic C.G.S. unit** (or absolute unit) is an **erg per second**. The **electrostatic C.G.S. unit** (or absolute unit) is the same **erg per second**.

Power Factor is a term used to show the amount of true power contained in a given amount of apparent power. It is the ratio of the true power to the apparent power. Its use is limited chiefly to electric power generated by alternating currents. With direct electric currents, the power is equal to the product of the volts and the amperes, and is called watts; with alternating currents, however, this is true only when the volts and amperes are exactly in phase with each other, which often is not the case. When there is such a difference in phase, that is when the current lags behind or precedes the voltage, their product is only **apparent power** and is usually measured in terms of the product of the volts and the amperes and called volt-amperes. If the **true power** in such a case is measured in watts, then the power factor will be the number of watts divided by the number of volt-amperes, and it will always be less than unity, in practice usually between 0.7 and 0.95. For true sine waves, the real power in watts is equal to the voltage $\times$ current $\times \cos \phi$, in which ϕ is the angular phase difference; hence it follows that in such cases the power factor is numerically equal to $\cos \phi$, whose numerical value is found directly from a table of cosines. Sometimes the power factor is stated in percent, in which case it is equal to the above figure multiplied by 100.

The **inductance factor** is the ratio of the wattless volt-amperes to the total volt-amperes; or the ratio of the wattless component of the current or the e.m.f. to the total current or e.m.f. The sum of the squares of the inductance factor and the power factor is equal to unity.

ELECTRICAL POWER.

	Logarithm
1 CGS unit (elmg) = 1 erg per second.....	0.000 0000
1 CGS unit (elst) = 1 erg per second	0.000 0000
1 absolute unit = 1 erg per second.....	0.000 0000
1 erg per second = 1 CGS unit (elmg).....	0.000 0000
“ = 1 CGS unit (elst).....	0.000 0000
“ = 10^{-7} watt.....	7.000 0000
1 microwatt = 10. ergs per second.....	1.000 0000
1 watt [W, w] = 10 000 000. ergs per second.	7.000 0000
“ = 1 joule per second.....	0.000 0000
1 kilowatt = 1 000 watts.....	3.000 0000

For further conversion factors, see table of units of Power, page 80.

The relations to other measures are as follows: †

Watts = volts $\times$ amperes.

“ = amperes² $\times$ ohms.

“ = volts² $\div$ ohms.

“ = coulombs $\times$ volts $\div$ seconds.

“ = coulombs² $\times$ ohms $\div$ seconds.²

“ = joules $\div$ seconds.

For alternating-current circuits: †

Watts = volts $\times$ amperes $\times$ cos ϕ .

“ = amperes² $\times$ ohms $\times$ cos ϕ .

“ = volts² $\times$ cos ϕ $\div$ ohms.

“ = effec. volts $\times$ effec. amp. $\times$ ohms resistance $\div$ ohms impedance.

“ = joules per cycle $\times$ frequency.

Mean watts = effective volts $\times$ effective amperes $\times$ cos ϕ .

Power factor = true power in watts $\div$ apparent power in volt-amperes.

“ = energy component of current or e.m.f. $\div$ total current or e.m.f.

“ = $\sqrt{(1 - \text{inductance factor}^2)}$.

Inductance factor:

= wattless component of current or e.m.f. $\div$ total current or e.m.f.

= $\sqrt{(1 - \text{power factor}^2)}$.

ELECTROCHEMICAL EQUIVALENTS and DERIVATIVES. (Weight $\div$ quantity of electricity; quantity of electricity $\div$ weight; weight $\div$ energy; energy $\div$ weight.)

The electrochemical equivalent of any chemical element or ion is the amount by weight which changes its chemical combination per coulomb of electricity during electrolysis. For these and their derivatives various compound units are used such as milligrams per coulomb, grams per ampere-hour, pounds per ampere-hour, etc. The relations between most of these are simply the relations between the respective units of weight, which see under Weights. The reciprocals of these are also used frequently.

The electrochemical equivalents of any elements or ions are, according to Faraday's law, proportional to their atomic weights and inversely proportional to their changes of valency. For determining the actual values, that of some one element must be determined experimentally, after which all the others can be calculated. In the following relations the value taken as a basis is the electrochemical equivalent of silver adopted by the International Electrical Congress of Chicago in 1893, in the definition of the ampere, and legal in this country, namely 0.001 118 gram per coulomb. The atomic weight of silver used in these relations is 107.93,

† Treatises on alternating currents should be consulted for the limiting conditions under which these relations apply to alternating or other periodically varying quantities.

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which is the usually accepted value on the basis of $O=16$. These fundamental values correspond with the usually accepted value of the ionic charge, 96 540. coulombs per monovalent gram ion, within the limits of accuracy of the data. For a complete table of the equivalents and their derivatives, of all the various elements and for various changes of valency, accompanied by descriptions of how to use them, see the author's *Table of Electrochemical Equivalents and their Derivatives*, in *Electrochemical Industry*, Jan., 1903, p. 169. The following relations apply to all elements or compounds. (The atomic weights are all based on oxygen=16, but the electrochemical equivalents are independent of whether the atomic weights are based on $O=16$ or on $H=1$.)

$$\left. \begin{array}{l} \text{Milligrams per coulomb} = 0.010\,359 \times \\ \text{Grams per ampere-hour} = 0.037\,291 \times \\ \text{Pounds per ampere-hour} = 0.000\,082\,21 \times \end{array} \right\} \frac{\text{atomic weight}}{\text{change of valency}}$$

$$\left. \begin{array}{l} \text{Grams per watt-hour} = 0.037\,291 \times \\ \text{Kilograms per kilowatt hour} = 0.037\,291 \times \\ \text{Kilograms per horse-power hour} = 0.027\,806 \times \\ \text{Pounds per kilowatt-hour} = 0.082\,21 \times \\ \text{Pounds per horse-power hour} = 0.061\,30 \times \end{array} \right\} \frac{\text{atomic weight}}{\text{change of val.} \times \text{volts.}}$$

$$\left. \begin{array}{l} \text{Coulombs per milligram} = 96.54 \times \\ \text{Ampere hours per gram} = 26.816 \times \\ \text{Ampere-hours per pound} = 12\,164. \times \end{array} \right\} \frac{\text{change of valency}}{\text{atomic weight.}}$$

$$\left. \begin{array}{l} \text{Watt-hours per gram} = 26.816 \times \\ \text{Kilowatt-hours per kilogram} = 26.816 \times \\ \text{Kilowatt-hours per pound} = 12.164 \times \\ \text{Horse-power hours per kilogram} = 35.964 \times \\ \text{Horse-power hours per pound} = 16.313 \times \end{array} \right\} \frac{\text{change of val.}}{\text{atomic weight}} \times \text{volts.}$$

Ionic charge for a monovalent gram ion = 96 539. coulombs.

For the **amount of gas** in cubic centimeters at 0°C . and 760 mm mercury pressure, developed at one electrode, on the basis that one gram molecule of a gas has a volume of 22.38 liters, the following relations exist, in which n is the number of atoms per molecule:

Cb. centimeters per ampere-hour = $834.6 \div (n \times \text{change of valency})$.

Ampere-hours per cb. centimeter = $0.001\,198 \times n \times \text{change of valency}$.

ELECTROLYTIC DEPOSITS. (Mass $\div$ time; mass $\div$ surface.)

Two kinds of units are used for measuring deposits, such as those in electrolysis. One is for measuring the weight of the deposit on a limited surface, and includes such units as **grams per square decimeter**, **ounces per square foot**, etc.; these are all given above in the same table as that for Pressures (page 63) and are therefore not repeated here

The other kind of unit is for measuring the rate of deposition, and includes such units as **milligrams per second**, **pounds per day**, **tons per year**, etc.; the reduction factors for these are given in the following table. The year is taken as equal to $365\frac{1}{4}$ days and the ton as equal to the short ton of 2000. pounds.

Aprx. means within 2%.

	Logarithm
1 pound (av) per year [lb/yr]:	
= 0.002 737 85 pound per day. Aprx. $1\frac{1}{4} \div 1\,000$	3.437 4098
= 0.000 862 409 gram per minute. Aprx. $\frac{6}{7} \div 1\,000$	4.935 7131
1 kilogram per year [kg/yr]:	
= 0.006 035 93 pound per day. Aprx. $6 \div 1\,000$	3.780 7440
= 0.002 737 85 kilogram per day. Aprx. $1\frac{1}{4} \div 1\,000$	3.437 4098
= 0.001 901 29 gram per minute. Aprx. $19 \div 10\,000$	3.279 0473

	Logarithm
1 gram per hour [g/h]:	
= 0.016 666 7 gram per minute, or $\frac{1}{60}$, which see.....	2.221 8487
1 milligram per second [mg/s]:	
= 0.06 gram per minute, which see for other values.....	2.778 1513
1 pound (av) per day [lb/day]	
= 365.25 pounds per year. Aprx. $\frac{11}{3} \times 100$	2.562 5902
= 165.675 kilograms per year. Aprx. $\frac{1}{6} \times 1\ 000$	2.219 2560
= 0.666 667 ounce per hour, or $\frac{2}{3}$	1.823 9087
= 0.453 592 kilogram per day. Aprx. $\frac{9}{2} + 10$	1.856 6658
= 0.314 995 gram per minute. Aprx. $31 + 100$	1.498 3033
= 0.182 625 ton (short) per year. Aprx. $\frac{11}{6} + 10$	1.261 5802
= 0.165 675 metric ton per year. Aprx. $\frac{1}{6}$	1.219 2560
= 0.041 666 7 pound per hour, or $\frac{1}{24}$	2.619 7888
= 0.018 899 7 kilogram per hour. Aprx. $19 + 1\ 000$	2.276 4546
1 ounce (av) per hour [oz/h]:	
= 1.5 pounds per day, or $\frac{3}{2}$	0.176 0913
= 0.680 389 kilogram per day. Aprx. $68 + 100$	1.832 7571
= 0.472 492 gram per minute. Aprx. $\frac{14}{3} + 10$	1.674 3946
1 kilogram per day [kg/day]:	
= 805.238 pounds per year. Aprx. 800.....	2.905 9244
= 365.250 kilograms per year. Aprx. $\frac{11}{3} \times 100$	2.562 5902
= 0.694 444 gram per minute. Aprx. $\frac{7}{10}$	1.841 6375
= 0.402 619 ton (short) per year. Aprx. $\frac{4}{10}$	1.604 8944
= 0.365 250 metric ton per year. Aprx. $\frac{11}{3} + 10$	1.562 5902
= 0.091 859 3 pound per hour. Aprx. $\frac{1}{11}$	2.963 1230
= 0.041 666 7 kilogram per hour, or $\frac{1}{24}$	2.619 7888
1 gram per minute [g/min]:	
= 1159.54 pounds per year. Aprx. $\frac{7}{6} \times 1\ 000$	3.064 2869
= 525.96 kilograms per year. Aprx. $\frac{1}{19} \times 10\ 000$	2.720 9527
= 60 grams per hour.....	1.778 1513
= 16.666 7 milligrams per second, or 100%.....	1.221 8487
= 3.174 66 pounds per day. Aprx. $\frac{32}{10}$	0.501 6967
= 1.440 00 kilograms per day. Aprx. $\frac{10}{7}$	0.158 3625
= 0.579 772 ton (short) per year. Aprx. $\frac{4}{7}$	1.763 2569
= 0.525 96 metric ton per year. Aprx. $\frac{10}{19}$	1.720 9527
= 0.132 277 pound per hour. Aprx. $\frac{4}{3} + 10$	1.121 4855
= 0.06 kilogram per hour.....	2.778 1513
1 ton (short) per year [tn/yr]:	
= 5.475 70 pounds per day. Aprx. $\frac{11}{2}$	0.738 4398
= 2.483 74 kilograms per day. Aprx. $\frac{19}{4}$	0.395 1056
= 1.724 82 grams per minute. Aprx. $\frac{7}{4}$	0.236 7431
= 0.228 154 pound per hour. Aprx. $\frac{9}{4} + 10$	1.358 2286
= 0.103 489 kilogram per hour. Aprx. $\frac{3}{3} + 10$	1.014 8944
1 metric ton per year [t/yr]:	
= 6.035 93 pounds per day. Aprx. 6.....	0.780 7440
= 2.737 85 kilograms per day. Aprx. $\frac{3}{11} \times 10$	0.437 4098
= 1.901 29 grams per minute. Aprx. $\frac{19}{10}$	0.279 0473
= 0.251 497 pound per hour. Aprx. $\frac{1}{4}$	1.400 5328
= 0.114 077 kilogram per hour. Aprx. $\frac{8}{7}$	1.057 1986
1 pound (av) per hour [lb/h]:	
= 8 766. pounds per year. Aprx. $\frac{7}{8} \times 10\ 000$	3.942 8015
= 3 976.19 kilograms per year. Aprx. 4 000.....	3.599 4672
= 10.886 2 kilograms per day. Aprx. 11.....	1.036 8770
= 7.559 87 grams per minute. Aprx. $\frac{3}{4} \times 10$	0.878 5145
= 4.383 tons (short) per year. Aprx. $\frac{4}{6} \times 10$	0.841 7715
= 3.976 19 metric tons per year. Aprx. 4.....	0.599 4672
1 kilogram per hour [kg/h]:	
= 19 325.7 pounds per year. Aprx. 19 000.....	4.286 1356
= 8 766. kilograms per year. Aprx. $\frac{7}{8} \times 10\ 000$	3.942 8015
= 52.910 9 pounds per day. Aprx. 53.....	1.723 5454
= 16.666 7 grams per minute, or 100%.....	1.221 8487
= 9.662 86 tons (short) per year. Aprx. $\frac{29}{8}$ or $\frac{3}{31} \times 100$	0.985 1056
= 8.766 metric tons per year. Aprx. $\frac{7}{8} \times 10$	0.942 8015
1 ounce (av) per minute [oz/min]:	
= $3\frac{3}{4}$ pounds per hour, which see for other values.....	0.574 0313

ELECTROCHEMICAL ENERGY.

The term electrochemical energy is used to refer to electrical energy when it performs chemical work, or to chemical energy when it is set free as electrical energy. The most convenient unit for expressing electrochemical energy is the **joule**, as the calculations are then the simplest; the **calorie** is, however, the one generally used in tables which give the energy of combination of chemical compounds; values in calories or any other units of energy are readily reduced to joules with the aid of the reduction factors given under Energy, page 74. Care must be taken to distinguish between the large and the small calorie, a distinction which is often not made in text-books and tables.

There is a very simple and direct way of calculating how many **volts** will be required to decompose a chemical compound electrolytically, or how many **volts** will be generated in a battery in which chemical compounds are formed, when the heats or energies of combination of the compounds are known. It is sometimes called Thomson's law, and can be directly deduced from Faraday's law and the principle of the conservation of energy. It is important to remember, however, that the number of volts thus calculated is limited to that required to supply the necessary energy of decomposition, or that generated in a battery by the formation of compounds; it includes nothing more. The actual voltage involves some further correction factors, which, though generally small as compared with the voltage of decomposition, are sometimes of importance. Among these correction factors is the voltage required to overcome the resistance of the electrolyte; this depends on the current flowing and on the resistance of the electrolyte. Another correction factor is the Gibbs or Helmholtz temperature coefficient, namely the rate of change of the voltage with the temperature; this falls out when there is no such change, or in practice when this change is inappreciable. Another correction factor is what is called the "over-voltage"; this depends on the fact that it takes different voltages to set free the same gas at electrodes of different metals. For these correction factors treatises on electrochemistry should be consulted.

In this rule for calculating the voltage due to the heat of combination, which is given below, the constant is based on the relation between the joule and the calorie given in the table of units of Energy, and on the same fundamental electrochemical and chemical constants for silver which were used to calculate the reduction factors for Electrochemical Equivalents above, namely 0.001 118 gram per coulomb as the electrochemical equivalent of silver, and 107.93 as the atomic weight of silver, on the basis of $O = 16$. These fundamental values correspond with the usually accepted value of the ionic charge, 96 540. coulombs per monovalent gram ion, within the limits of accuracy of the data. For the heats of combination of compounds, see reference-books on this subject; the data are usually given in calories per gram molecule, but care must be taken to find out whether the large calorie or the small calorie is the one meant; also whether it is a gram molecule or a kilogram molecule that is meant; care must also be taken to see that the given number of calories apply to the exact decomposition or combination under consideration, whether gases are set free and escape as such, or whether they recombine, and if the latter, whether this recombination enters into the electrochemical reaction or whether it is purely chemical, as by local action, also whether water or some other accompanying product is formed or decomposed, etc.

Rule for calculating the voltage of decomposition or composition, from the heat of combination.

For monovalent ions, or for one equivalent weight:	Logarithm
The number of volts:	
= the number of kilogram calories per gram molecule $\times$ 0.043 363. Aprx. $\frac{3}{7} \div 10$	2.637 1162
= the number of kilogram calories per kilogram molecule, or gram calories per gram molecule, $\times$ 0.000 043 363. Aprx. $\frac{3}{7} \div 10\ 000$	5.637 1162
= the number of kilogram calories per gram molecule $\div$ 23.061. Aprx. $\frac{7}{3} \times 10$	1.362 8838
= the number of kilogram calories per kilogram molecule, or gram calories per gram molecule, $\div$ 23 061. Aprx. $\frac{7}{3} \times 10\ 000$	4.362 8838

For multivalent ions divide the volts thus obtained by the valency. That is, for bivalent ions calculate the voltage from the above and then divide by 2; for trivalent ions divide by 3, etc. Or the number of calories may be reduced to that for one equivalent weight (by dividing the calories by the valency), and the above rules will then give the volts directly.

MAGNETIC RELUCTANCE [$\mathcal{R}$, R]; MAGNETIC RESISTANCE. (Magnetomotive force $\div$ flux; length $\div$ (surface $\times$ permeability).)

Reluctance measures the amount by which the material in a magnetic circuit or part of a circuit resists or opposes the flux; the more it resists, the greater the reluctance; it is the opposite to permeance and numerically it is equal to the reciprocal of permeance. As the reluctance of a centimeter cube of air (or more correctly, of a vacuum) in the C.G.S. system is, by definition, equal to unity (that is, to one oersted), it follows that the amount of reluctance of any magnetic circuit or any part of it also represents the number of times that its reluctance is greater than that of the air of the same volume and shape. Reluctance is analogous to resistance in an electric circuit, but differs in these three important features: (1) in circuits containing magnetic materials it generally varies very greatly with the flux density, being constant only for air or other diamagnetic materials; (2) there is no such a thing as a magnetic insulator, that is, an infinitely great reluctance; (3) maintenance of a flux through a reluctance does not necessarily require the continuous expenditure of energy. A reluctance in oersteds is equal to the magnetomotive force in gilberts divided by the flux in maxwells. The reluctance of a circuit in oersteds is equal to the length of the circuit in centimeters divided by its cross-section in square centimeters and then either multiplied by the reluctivity or divided by the permeability; but in magnetic materials the reluctivity and the permeability vary with the density of the flux in the circuit, hence this method of calculation is practicable only for non-magnetic materials like air, the permeability of which is constant and is equal to unity; it may be applied to air-gaps, for instance. The reluctance is not used very often in magnetic calculations, these being usually based on the property called permeability, as is explained below under the units of magnetizing force.

The only unit used is the C.G.S. unit called an oersted, which is the reluctance through which a C.G.S. unit of magnetomotive force (called a gilbert) will produce a C.G.S. unit of flux (called a maxwell).

1 CGS unit (elmg) = 1 oersted.
 1 oersted = 1 CGS unit (elmg).

The relations to other measures are as follows:

Oersteds:

- = gilberts $\div$ maxwells.
- = gilberts $\div$ (gausses $\times$ sq. centimeters section).
- = ampere-turns $\times 1.256\ 64\ddagger \div$ maxwells.
- = ampere-turns $\times 1.256\ 64\ddagger \div$ (gausses $\times$ sq. centimeters section).
- = CGS unit of current-turns $\times 12.566\ 4\ddagger \div$ maxwells
- = CGS unit current-turns $\times 12.566\ 4\ddagger \div$ (gausses $\times$ sq. cm. section).
- = 1 $\div$ permeance in CGS units.
- = centimeters length $\div$ (sq. centimeters section $\times$ permeability).
- = centimeters length $\times$ relativity $\div$ sq. centimeters section.
- = inches length $\times 0.393\ 700 \div$ (sq. inches section $\times$ permeability).
- = inches length $\times$ relativity $\times 0.393\ 700 \div$ sq. inches section.
- = (number of turns $\times 0.000\ 1)^2 \times 1.256\ 64\ddagger \div$ henrys.

Oersteds in iron = oersteds in air $\div$ permeability.

“ in air = oersteds in iron $\times$ permeability

MAGNETIC RELUCTIVITY [ν]; SPECIFIC MAGNETIC RELUCTANCE; MAGNETIC RESISTIVITY; SPECIFIC MAGNETIC RESISTANCE. ($1 \div$ permeability; magnetizing force $\div$ magnetic induction; reluctance $\times$ surface $\div$ length; reluctance $\div$ reluctance.)

Reluctivity measures the number of times that a material resists or opposes magnetic flux, more than air (or vacuum) does. It is a property of a material and numerically it is equal to the reciprocal of the permeability, which see. It corresponds in some respects to resistivity or specific resistance in electrical circuits. It is specific reluctance based on air; but as the reluctivity of air is unity, that of any other material is numerically equal to the reluctance in oersteds of a centimeter cube of that material. Reluctivity is seldom used in magnetic calculation, its reciprocal, the permeability, being used instead. Like permeability, it is a property of the material in a magnetic circuit, and its values are different with different flux densities.

There are no units, as it is a mere ratio. The relations of reluctivity to other magnetic measures are the reciprocals of those for permeability.

The chief relations are:

Reluctivity = $1 \div$ permeability.

“ = sq. centimeters section $\times$ oersteds $\div$ centimeters length.

“ = sq. inches section $\times$ oersteds $\times 2.540\ 01 \div$ inches length.

MAGNETIC PERMEANCE; MAGNETIC CONDUCTANCE; MAGNETIC CAPACITY. ($1 \div$ reluctance; flux $\div$ magnetomotive force; surface $\div$ (length $\times$ permeability).)

Permeance measures the amount by which a given magnetic circuit conducts the flux, the better it conducts, the greater the permeance; it is the opposite to reluctance, and numerically it is equal to the reciprocal of reluctance. It is analogous to conductance in an electrical circuit. Just as the reluctance of a given magnetic circuit refers to that particular circuit or its parts, so permeance refers to a particular magnetic circuit or its parts. In referring to the property of the material itself, independently of its

$\ddagger$ Or $4\pi/10$. Aprx. $\frac{1}{8} \times 10$. Log 0.099 2099.

$\ddagger$ Or 4π . Aprx. $\frac{1}{8} \times 100$. Log 1.099 2099

size and shape, the term permeability or specific permeance is used, which see below. When a given magnetic circuit contains a magnetic material like iron, the permeance does not remain constant like the conductance of an electric circuit, but it varies very greatly with the density of the flux; it is constant only for air. Permeance is seldom used in magnetic calculations (see under magnetizing force). It can always be avoided by using the reciprocal of the reluctance instead; both may be avoided by basing the calculations on the permeability.

The unit is the **C.G.S. unit**, which is the reciprocal of the absolute or C.G.S. unit of reluctance, that is, the reciprocal of an oersted; it has no name. The permeance of a centimeter cube of air (or vacuum) between two parallel sides is unity in the C.G.S. system. Hence the permeance of a magnetic circuit or of a part of it, also represents the number of times that its permeance is greater than that of an equal volume of air of the same size and shape. It is equal, in C.G.S. units, to the permeability multiplied by the cross-section in square centimeters and divided by the length in centimeters.

The relations to other measures are as follows:

Permeance = maxwells ÷ gilberts.

" = 1 ÷ oersteds.

" = permeability × sq. centimeters section ÷ centimeters length.

" = permeability × sq. inches section × 2.540 01 ÷ inches length.

Permeance of iron = permeance of air × permeability.

" of air = permeance of iron ÷ permeability.

See also the reciprocals of the relations given under Reluctance.

MAGNETIC PERMEABILITY [μ]; SPECIFIC PERMEANCE; MAGNETIC CONDUCTIVITY. (Magnetic induction ÷ magnetizing force; flux density ÷ flux density; permeance ÷ permeance; 1 ÷ reluctivity.)

Permeability is a very important quantity in most magnetic calculations; it measures the number of times that a material conducts or aids magnetic flux better than air does; if, for instance, the permeability of a certain kind of iron under certain conditions is 300, it means that it conducts magnetic flux or lines of force 300. times as well as an equal amount of air would under the same conditions, that is, it is 300. times as permeable to the flux. It may be said to be magnetic conductivity compared to air as a standard. If a given magnetomotive force produces a certain amount of flux in a given circuit of air, it will produce 300. times this flux if the air were replaced by this kind of iron. It follows from this that the magnetizing force (usually represented by H) multiplied by the permeability (μ) gives the induction (B) in the iron, that is, the flux density in the iron; or permeability = induction ÷ magnetizing force; this is further explained under the units of magnetizing force. Permeability is an inherent property of materials and its values are usually given in tables or curves. It is also the same as specific permeance, which is the permeance of a material as compared with that of air; as the permeance of a centimeter cube of air is unity, the law above given follows. Permeability is the reciprocal of reluctivity. It is analogous to conductivity or specific conductance in electrical calculations, with a very important difference, however, namely that while the electrical conductivity of a material is constant and does not change with the current which flows, the permeability of the chief magnetic materials varies very greatly with the density of the flux, and its values must therefore be given for each flux density, for which reason they are usually given in the form of curves called permeability curves or magnetization curves. For air, however, the permeability is always constant and is numerically equal to unity. Paramagnetic bodies are those whose permeability is greater than unity, and diamagnetic bodies those whose permeability is less than unity.

There are no units of permeability, as it is a mere relation, number, or ratio between two quantities of the same kind. In this respect it is like specific gravity.

For a brief description of calculations involving permeabilities see under the units of Magnetizing Force.

The relations to other measures are as follows:

Permeability:

- =gausses in iron ÷ gaussses in air.
- =inch gaussses in iron ÷ inch gaussses in air.
- =permeance of iron ÷ permeance of air.
- =oersteds of air ÷ oersteds of iron.
- =1 ÷ reluctivity.
- =1 ÷ [susceptibility × 12.566 4 (or 4π)].
- =gausses ÷ gilberts per centimeter.
- =gausses × 0.795 775 (or $10 \div 4\pi$) ÷ ampere-turns per centimeter.
- =gausses × 2.540 01 ÷ gilberts per inch.
- =gausses × 2.021 27 ÷ ampere-turns per inch.
- =inch gaussses × 0.393 700 ÷ gilberts per inch.
- =inch gaussses × 0.313 297 ÷ ampere-turns per inch.
- =gausses × 0.079 577 5 (or $1 \div 4\pi$) ÷ CGS unit current-turns per cm.
- =centimeters length ÷ (sq. centimeters section × oersteds).
- =inches length × 0.393 700 ÷ (sq. inches section × oersteds).
- =permeance × centimeters length ÷ sq. centimeters.

For the relations with maxwells substitute for "gausses," in any of the above, "maxwells ÷ sq. centimeters section"; and for "inch gaussses," substitute "maxwells ÷ sq. inches section."

MAGNETIC SUSCEPTIBILITY [κ]. (Intensity of magnetization ÷ magnetizing force.)

This quantity is used chiefly in physical conceptions; it is somewhat similar to permeability in that it expresses the magnetizability of a substance. It is equal to the intensity of magnetization (see below) divided by the magnetizing force which produces it. There are no units, as it is a mere ratio or number. Its relation to permeability is as follows:

Susceptibility = (permeability - 1) × 0.079 577 5 (or $1 \div 4\pi$).

MAGNETOMOTIVE FORCE [m.m.f. $\mathcal{F}$, F]; AMPERE-TURNS [a-t]; MAGNETIC POTENTIAL; DIFFERENCE OF MAGNETIC POTENTIAL; MAGNETIC PRESSURE. (Current × turns; flux × reluctance; energy ÷ pole strength.)

These units are used to measure the magnetic pressure or "motive force" which produces or tends to produce a magnetic flux in a magnetic circuit, just as an electromotive force tends to produce a current of electricity, or a pressure of water tends to produce a flow of water and might similarly be called the hydraulic motive force. In practice magnetomotive forces are generally produced by, and are often measured in terms of, what are called ampere-turns; this term means the product of an electric current in amperes and the number of turns or windings of the coil through which it flows; such a current-carrying coil produces a definite magnetomotive force, which in turn produces an amount of flux dependent on the amount of reluctance in the whole magnetic circuit. According to the laws of electromagnetism, the magnetomotive force in C.G.S. units (gilberts) is always numerically equal to the ampere-turns multiplied by $4\pi \div 10$, whether

there is iron in the magnetic circuit or not. The magnetomotive force in gilberts in any closed loop encircling a long straight wire through which a current passes is 4π times the C.G.S. unit of current, or $4\pi \div 10$ times the number of amperes. It is always directly proportional to the current producing it. The law of the magnetic circuit is similar to Ohm's law for the electric circuit, namely that the flux (corresponding to the current) is equal to the magnetomotive force (corresponding to the electromotive force), divided by the reluctance (corresponding to the resistance); hence the magnetomotive force in C.G.S. units (gilberts) is equal to the flux in C.G.S. units (maxwells) multiplied by the reluctance in C.G.S. units (oersteds). This is true whether there is iron in the magnetic circuit or not.

Most calculations occurring in practice are simplified by using the quantity called the magnetizing force instead of the magnetomotive force, as is explained below under the units of Magnetizing Force.

There are three units of magnetomotive force in use; the more general, and often the more convenient one, is the **ampere-turn**, which is equal to the magnetomotive force produced by one ampere flowing once around a magnetic circuit; this is irrespective of the shape or size of the electric or magnetic circuit; the latter affect only the reluctance of the magnetic circuit and thereby the resulting flux. This unit bears an incommensurate relation to the absolute magnetic units owing to the factor 4π .

The second usual unit is the **electromagnetic C.G.S. unit** (or absolute unit), called a **gilbert**. Its definition is based on the fact that the magnetomotive force produced in any one closed loop around a long straight wire through which a C.G.S. unit of current (or 10 amperes) flows, is 4π C.G.S. units of magnetomotive force; hence one such unit is equal to $1 \div 4\pi$ of this magnetomotive force. It may also be defined as that magnetomotive force which will produce a flux of one C.G.S. unit (maxwell) through one C.G.S. unit of reluctance (oersted).

The third unit is like the ampere-turn except that the current is the C.G.S. unit of current (10 amperes) instead of the ampere. This unit is therefore equal to 10 times the ampere-turn unit. It has no name other than the **C.G.S. unit current-turn**. It is never used in practice.

Logarithm

1 CGS unit (elmg) = 1 gilbert, which see for other values.

1 gilbert:

=	1 CGS unit (elmg) of magnetomotive force.	
=	0.795 775 (or $10/4\pi$) ampere-turn. Aprx. subtr. $\frac{1}{2}\%$	1.900 7901
=	0.079 577 5 (or $1/4\pi$) CGS unit of current-turn. Aprx. $\frac{8}{100}\%$	2.900 7901
1 ampere-turn =	1.256 637 (or $4\pi/10$) CGS units. Aprx. add $\frac{1}{4}\%$	0.099 2099
"	= 1.256 637 (or $4\pi/10$) gilberts. Aprx. add $\frac{1}{4}\%$	0.099 2099
"	= 0.1 CGS unit of current-turn.	1.000 0000
1 CGS unit of current-turn:		
=	12.566 37 (or 4π) CGS units (elmg). Aprx. 100%	1.099 2099
=	12.566 37 (or 4π) gilberts. Aprx. 100%	1.099 2099
=	10. ampere-turns	1.000 0000

The relations to other measures are as follows:

Gilberts:

- = ampere-turns $\times 1.256\ 64$.
- = CGS unit current-turns $\times 12.566\ 4$.
- = maxwells $\times$ oersteds.
- = maxwells $\div$ permeance (in CGS (elmg) units).
- = maxwells $\times$ cm length $\div$ (sq. cm section $\times$ permeability).
- = maxwells $\times$ inches length $\times 0.393\ 700 \div$ (sq. inches section $\times$ permeability).
- = maxwells $\times$ centimeters length $\div$ sq. centimeters section. For air.
- = maxwells $\times$ ins. length $\times 0.393\ 700 \div$ sq. ins. section. For air.
- = gaussses $\times$ centimeters length $\div$ permeability.
- = gaussses $\times$ inches length $\times 2\ 540\ 01 \div$ permeability.
- = inch gaussses $\times$ inches length $\times 0.393\ 700 \div$ permeability.
- = gaussses $\times$ centimeters length. For air.
- = gaussses $\times$ inches length $\times 2.540\ 01$. For air.
- = inch gaussses $\times$ inches length $\times 0.393\ 700$. For air.
- = gaussses $\times$ oersteds $\times$ sq. centimeters section.

† Or $4\pi/10$. Aprx. add $\frac{1}{4}\%$. Log 0.099 2099.

‡ Or 4π . Aprx. $\frac{1}{2}\% \times 100$. Log 1.099 2099.

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Gilberts for iron = gilberts for air + permeability.

Gilberts for air = gilberts for iron $\times$ permeability.

Ampere-turns:

= gilberts $\times 0.795\,775$.†

= CGS unit current-turns $\times 10$,

= maxwells $\times$ oersteds $\times 0.795\,775$.†

= maxwells $\times 0.795\,775$ † $\div$ permeance (in CGS (elmg) units).

= maxwells $\times$ cm length $\times 0.795\,775$ † $\div$ (sq. cm section $\times$ permeability).

= maxwells $\times$ ins. length $\times 0.313\,296$ $\div$ (sq. ins. section $\times$ permeability).

= maxwells $\times$ cm length $\times 0.795\,775$ † $\div$ sq. cm section. For air.

= maxwells $\times$ ins. length $\times 0.313\,296$ $\div$ sq. ins. section. For air.

= gaussses $\times$ centimeters length $\times 0.795\,775$ † $\div$ permeability.

= gaussses $\times$ inches length $\times 2.021\,27$ $\div$ permeability.

= inch gaussses $\times$ inches length $\times 0.313\,296$ $\div$ permeability.

= gaussses $\times$ centimeters length $\times 0.795\,775$.† For air.

= gaussses $\times$ inches length $\times 2.021\,27$. For air.

= inch gaussses $\times$ inches length $\times 0.313\,296$. For air.

= gaussses $\times$ oersteds $\times$ sq. centimeters section $\times 0.795\,775$.†

Ampere-turns for iron = ampere-turns for air $\div$ permeability.

Ampere-turns for air = ampere-turns for iron $\times$ permeability.

CGS unit of current-turns = ampere-turns $\times 0.1$.

= gilberts $\times 0.079\,577\,5$.†

(For further relations divide those for ampere-turns by 10.)

When the flux is due only to the current, as in self-induction, and when there is no magnetic leakage:

Ampere-turns = ergs of kinetic energy of the current $\times 20 \div$ maxwells.

" = joules of kinetic energy of the current $\times 2 \times 10^8 \div$ maxwells.

" = maxwells $\times$ number of turns² $\div$ (henrys $\times 10^8$).

When the flux is from an external source, and independent of the current as in mutual induction, and when there is no magnetic leakage:

Ampere-turns = ergs of kinetic energy of the current $\times 10 \div$ maxwells.

" = joules of kinetic energy of the current $\times 10^8 \div$ maxwells.

MAGNETIZING FORCE [$\mathcal{H}$, H]; MAGNETOMOTIVE FORCE per CENTIMETER; MAGNETIC FORCE; FIELD INTENSITY. (Turns $\times$ current $\div$ length; magnetomotive force $\div$ length; induction $\div$ permeability; flux density $\div$ permeability; force $\div$ pole strength.)

This quantity, which is one of the most important in the more usual magnetic calculations, is used to measure the magnetomotive force produced per unit length of a coil or solenoid carrying an electric current; or the magnetomotive force required per unit length of any part of a magnetic circuit to produce the desired flux density in that part. The usual calculations of magnetic circuits then often become simpler than they would be if the whole magnetomotive force itself is used. In electric circuits it has its analogy in the electromotive force produced per centimeter length of active wire in an armature of a dynamo or in a transformer, or the difference of potential required per centimeter length of a conductor in order to produce the desired current density in that conductor.

There are no specifically named units of magnetizing force. The one most frequently used when the metric system is employed, is an **ampere-turn per centimeter** length. When inches are used the unit is an **ampere-turn per inch**. The absolute or C.G.S. unit is one **gilbert per centimeter**. When the magnetic circuit consists of air, the magnetizing

† Or $10 \div 4\pi$. Aprx. $\frac{8}{10}$. Log I.900 7901.

† Or $1 \div 4\pi$. Aprx. $8 \div 100$. Log $\bar{2}$.900 7901.

force can also be expressed and measured in terms of units of flux density, namely **gausses**, for, although they mean something different, they are numerically the same as gilberts per centimeter for air, as is shown below.

If a current flows through a uniform coil of wire which is very long as compared with its diameter, the flux density produced in its interior will be practically uniform except near its ends; it will be nearly uniform throughout if the two ends are brought together to form a ring coil. Moreover, this flux density is independent of the diameter of the coil or the shape of its cross-section, which affect only the reluctance and the total flux.

The magnetizing force produced by such a coil, whether it contains iron or not, is numerically equal in gilberts per centimeter to $4\pi nc$, in which n is the number of turns or windings per centimeter length of coil, and c is the current in absolute units; nc is therefore the number of current-turns per centimeter, corresponding to (but not numerically equal to) the ampere-turns per centimeter. Imagine a series of planes perpendicular to the axis and one centimeter apart; then the magnetizing force given by this formula will be the magnetomotive force in gilberts produced between each plane and the next. As an analogy, suppose the interior were replaced by a conductor carrying an electric current, and the coil itself were replaced by a device which induces an electromotive force in that conductor, then the volts induced per centimeter length of this device will evidently be the volts of electromotive force which exist between each of these parallel planes and the next.

It is also true for iron as well as for air that the magnetizing force equals the flux density divided by the permeability, but as the permeability of air is unity by definition, it follows that *for air* (or more exactly for a vacuum) the magnetizing force of such a coil when expressed in gilberts per centimeter, is numerically equal to the flux density in its interior in gauss. The above general formula therefore also gives, as a special case, the flux density in air in gauss. This has given rise to much confusion, as it makes it appear at first sight as though a magnetomotive force was of the same nature as a flux density, which with the electric units would be like saying that an electromotive force was of the same nature as a current density. The explanation is that the reluctance of a centimeter cube of air is unity, hence the flux density in gauss through each centimeter cube of air will be numerically the same as the magnetomotive force in gilberts acting between its two opposite faces; or in the above illustration with the imaginary parallel planes one centimeter apart, the flux density in gauss in each space between two such planes will for air be numerically equal to the magnetomotive force (in gilberts) between each plane and the next. Analogously, if a wire happens to have a resistance of one ohm per foot, the number of volts acting at the ends of each foot will be numerically the same as the number of amperes flowing. The identity is in the numbers and not necessarily in the nature of the units; moreover, the numerical identity exists only between the units gilberts per centimeter and gauss, and not between the other units like ampere-turns.

The formula $4\pi nc$ therefore always gives the magnetizing force produced in gilberts per centimeter length of coil, whether there is iron in the coil or not. It also gives the flux density in gauss in the interior of the coil, but for air only. c is the current in absolute units and must be replaced in the formula by $C \div 10$, if C is to be in amperes. When the result given by this formula is multiplied by the entire length of the coil in centimeters, it gives the total magnetomotive force of the whole coil, in gilberts.

The same magnetizing force will produce entirely different flux densities in materials of different permeabilities, just as the same voltage will produce entirely different currents in materials of different conductivities. The magnetizing force in gilberts per centimeter multiplied by the permeability of any material gives the flux density in gauss, or the induction in gauss, produced in that material by that magnetizing force. Or in different terms, if a coil produces in its interior a certain flux density in gauss in air, then that flux density must be multiplied by the permeability of the material to get the flux density or induction in that material in gauss, when the air circuit is completely replaced by that material, as in transformers; for the case in which the circuit is partly air and partly iron, see the next paragraphs. The more usual calculations, such as those for dynamos and transformers, start with the desired induction, and in order to avoid the calculation of the reluctance, the troublesome factor 0.4π , and

the various other reduction factors when inch units are used, such calculations are generally made as described in the following paragraphs.

Magnetic calculations, like those for dynamos and transformers. The values of the permeabilities of the particular iron or steel which is to be used, are usually given in the form of a curve called a permeability curve or a magnetization curve, whose horizontal distances are the magnetizing forces in ampere-turns per centimeter (H), and whose vertical ones are the corresponding inductions (B) or flux densities, in gaussses or lines of force per square centimeter in that quality of iron or steel. It must be decided at the start what the inductions are to be in the various parts of the circuit; then from the curve for the kind of iron in each part, find what the required magnetizing force is in ampere-turns per centimeter for that part; then multiply this by the axial or center-line length in centimeters, of this particular part of the iron under consideration, be it the cores or the yoke-pieces, or the armature, and the result will be the total number of ampere-turns or the magnetomotive force, which is required to magnetize that part to that particular induction. Notice that the length here used is that of the path of the flux through that part of the iron, and not necessarily the length of the coil. Having done this for each of the iron parts making up the whole circuit, add them all together and the result will be the total ampere-turns required for the total iron part of the circuit. The ampere-turns required for producing the flux in the air-gap are calculated from the desired flux density in the gap, as follows: ampere-turns = flux density in gaussses $\times$ length of air-path of flux (that is, twice the length of the gap) in centimeters $\times 0.795775$. These latter ampere-turns (which generally are by far the larger part of the whole) are then added to those required for the iron part, thus giving the total required for the complete magnetic circuit. The coils for producing these ampere-turns may have any length and may be wound around any convenient part of the circuit, for when the magnetic circuit is chiefly of iron, the magnetizing force of the coils will act in that circuit very nearly the same way no matter how they are distributed over the iron.

When the dimensions are all in inches and the flux densities in maxwells per square inch (inch-gaussses), then the magnetization curve should be plotted for those units and the calculations are then precisely the same except for the air-gap, for which the formula then becomes: ampere-turns = flux density in maxwells per sq. inch $\times$ length of air-path of flux in inches $\times 0.313296$.

When the linear dimensions are in inches, and the flux densities in gaussses, the curve should be plotted accordingly and the calculations are again the same except for the air-gap, for which the formula then becomes: ampere-turns = gaussses $\times$ length of air-path of flux in inches $\times 2.02127$.

It will be noticed that in this method of calculation the reluctance need not be known. The total required cross-section of the iron is determined by dividing the given total flux by the given flux density. The reverse calculation to the above is much more difficult; in that case the ampere-turns of such a composite magnetic circuit together with all the dimensions are given, and the flux produced by them is to be determined. In such a case perform the calculation backwards, by making trial calculations as just described, using different assumed total fluxes, until one is found which will require the given number of ampere-turns. For a simple magnetic circuit like that in a transformer, in which there is no air-gap, either calculation amounts to little more than reading off the results from the magnetization curve.

Logarithm

1 gilbert per inch:

= 0.795775 ampere-turn per inch. Aprx. subt. $\frac{1}{8}$	1.900 7901
= 0.393700 gilbert per centimeter. Aprx. $\frac{4}{10}$	1.595 1654
= 0.313296 ampere-turn per centimeter. Aprx. $\frac{1}{16}$	1.495 9555

1 ampere-turn per inch:

= 1.25664 gilberts per inch. Aprx. add $\frac{1}{4}$	0.099 2099
= 0.494738 gilbert per centimeter. Aprx. $\frac{1}{2}$	1.694 3753
= 0.393700 ampere-turn per centimeter. Aprx. $\frac{4}{10}$	1.595 1654

1 gilbert per cm = 2.54001 gilberts per inch. Aprx. $\frac{10}{4}$	0.404 8346
" = 2.02127 ampere-turns per inch. Aprx. 2.	0.305 6247
" = 1. CGS unit (elmg)	0.000 0000
" = 0.795775 amp. turn per cm. Ap. subt. $\frac{1}{8}$	1.900 7901

	Logarithm
1 CGS unit (elmg)=1. gilbert per centimeter.	0.000 0000
1 ampere-turn per cm:	
=3.191 86 gilberts per inch. Aprx. $3\frac{1}{5}$	0.504 0445
=2.540.01 ampere-turns per inch. Aprx. $10\frac{1}{4}$	0.404 8346
=1.256 64 gilberts per cm. Aprx. add $\frac{1}{4}$	0.099 2099
1 CGS unit of current-turn per centimeter:	
=31.918 6 gilberts per inch. Aprx. 32.	1.504 0445
=25.400 1 ampere-turns per inch. Aprx. 25.	1.404 8346
=12.566 4 gilberts per centimeter. Aprx. $\frac{1}{8}\times 100$	1.099 2099
=10. ampere-turns per centimeter.	1.000 0000

For air (or vacuum) only:

1 gauss=1 gilbert per centimeter.

The relations to other measures are as follows:

Ampere-turns per centimeter:

- =gausses $\times 0.795\,775\ddagger \div$ permeability.
- =maxwells $\times 0.795\,775\ddagger \div$ (sq. cm section $\times$ permeability).
- =gausses $\times 0.795\,775\ddagger$. For air.
- =maxwells $\times 0.795\,775\ddagger \div$ sq. cm section. For air.

Ampere-turns per inch:

- =gausses $\times 2.021\,27 \div$ permeability.
- =maxwells $\times 0.313\,297 \div$ (sq. inches section $\times$ permeability).
- =inch gausses $\times 0.313\,296 \div$ permeability.
- =gausses $\times 2.021\,27$. For air.
- =maxwells $\times 0.313\,297 \div$ sq. inches section. For air.
- =inch gausses $\times 0.313\,296$. For air.

Gilberts per centimeter=gausses $\div$ permeability.

“=maxwells $\div$ (sq. cm section $\times$ permeability).

“=gausses. For air.

“=maxwells $\div$ sq. centimeters. For air.

Gilberts per inch:

- =gausses $\times 2.540\,01 \div$ permeability.
- =maxwells $\times 0.393\,700 \div$ (sq. inches section $\times$ permeability).
- =inch gausses $\times 0.393\,700 \div$ permeability.
- =gausses $\times 2.540\,01$. For air.
- =maxwells $\times 0.393\,700 \div$ sq. inches section. For air.
- =inch gausses $\times 0.393\,700$. For air.

CGS unit of current-turns per centimeter:

- =gausses $\times 0.079\,577\,5\ddagger \div$ permeability.
- =gausses $\times 0.079\,577\,5\ddagger$. For air.

MAGNETIC FLUX [Φ , ϕ]; LINES OF FORCE; FLUX OF FORCE; AMOUNT OF MAGNETIC FIELD; POLE STRENGTH [m]. (Magnetomotive force $\div$ reluctance; magnetic induction (or flux density) $\times$ surface; electromotive force $\times$ time; length $\times \sqrt{\text{force}}$.)

These units are used to measure the total quantity or amount or number of magnetic lines of force or the amount of flow or flux of magnetism, just as amperes are used to measure the quantity or amount of electric current, or as cubic feet per second measure the amount of a flow of water. This magnetic flux or flow is in some respects analogous to a current of electricity, as it must always form a closed circuit upon itself, and be the same in amount in every cross-section of the circuit; it follows a law analogous to Ohm's law, as the flux is equal to the magnetomotive force divided by the

$\ddagger$ Or $10 \div 4\pi$. Aprx. 8/10. Log 1.900 7901.

$\ddagger$ Or $1 \div 4\pi$. Aprx. 8/100. Log 2.900 7901.

reluctance. It differs, however, in that no work is being done continuously in the circuit of a magnetic flux, and it can therefore continue to exist indefinitely as in a permanent magnet, without consuming or producing energy. Energy is stored in the flux when it is produced, and it is given out again whenever the flux ceases to exist, but no energy is necessarily required to maintain it; it is therefore in this respect more like a mechanical pressure or stress, as that of compressed air. The kinetic energy (which see above) required to start an electric current is stored in the system as magnetic energy, and given out again as electrical energy when the current stops. From the energy standpoint, magnetic flux is more analogous to coulombs of electricity. A magnetic circuit also differs from an electric circuit in that it can never be opened, as there is no such a thing as a magnetic insulator; magnetic flux can cease only by contracting to a point somewhat like an extremely small rubber band which is allowed to contract after having been stretched.

The space surrounding a magnet or an electric current or that between two magnetic poles, is called a **magnetic field** or **magnetic field of force**, as it contains magnetic flux or magnetic lines of force; units of flux measure the total amount of this field (but not its intensity or density) or the total number of such lines of force; this flux also continues through the magnet itself.

Flux is also equal to the flux density (sometimes called induction), in lines of force per square centimeter (or per square inch), multiplied by the number of square centimeters (or square inches) cross-section of its path, and is then often called the total flux to distinguish it from the flux density. An electric current is always encircled by such flux, and the two circuits, namely the electric and the magnetic, are always linked together like the two links of a chain. When the magnetic flux enclosed in a coil or loop of wire is increased or diminished, an electromotive force is produced in that wire; this is the fundamental principle of a dynamo; or stated in different terms, when a wire cuts through magnetic flux, an electromotive force is produced in the wire; or the linking and unliking of circuits of flux and electric circuits produces an electromotive force; it is this that produces self- and mutual induction.

The term **flux-turns** or **mean flux-turns** is sometimes used for denoting the product of the number of turns and the mean flux (in maxwells) in one turn; the magnetic leakage is thereby eliminated. The mean flux-turns in maxwell-turns are equal to the self-inductance in henrys multiplied by 10^8 times the final current in amperes.

The **unit** universally used is the absolute or **electromagnetic C.G.S. unit** or **single line of force**, and is defined as that amount of flux which acting on a unit magnetic pole will propel it with a force of one dyne. It can also be defined as the amount of flux passing through one square centimeter cross-section of a field having a flux density of one C.G.S. unit. A **unit magnetic pole** (imaginary) is one which will exert a force of one dyne on another unit pole one centimeter distant. From each such pole there radiates a flux equal to 4π (or 12.566 4) of these units or lines of force.

A single or unit line of force in a magnetic field may be said to stand for or represent a tube of such a cross-section that it always embraces a unit of flux; a definite amount of flux may have widely different lengths of circuit or cross-sections without changing its amount.

This C.G.S. unit is called a **maxwell**, according to the International Congress of 1900. A maxwell is therefore the same thing as a single or unit line of force as above defined.

	Logarithm
1 CGS unit (elmg) = 1 maxwell.	0.000 0000
1 maxwell:	
= 1 CGS unit (elmg).	0.000 0000
= 1 line of force.	0.000 0000
= 1 gauss-centimeter ²	0.000 0000
= 0.155 000 gauss-inch ² . Aprx. $\frac{2}{13}$	1.190 3308
= 0.079 577 5 (or $\frac{1}{4}\pi$) of the flux from a unit pole. Aprx. $\frac{1}{100}$	2.900 7901
1 weber (obsolete) = 1 maxwell.	0.000 0000
1 unit pole (flux from) = 12.566 37 (or 4π) maxwells.	1.099 2099
1 Kapp line (obsolete) = 6 000. maxwells.	3.778 1513

The relations to other measures are as follows:

Maxwells:

- =gausses $\times$ sq. centimeters.
- =inch-gausses $\times$ sq. inches.
- =gilberts $\div$ oersteds.
- =gilberts $\times$ permeance (in CGS units).
- =gilberts $\times$ permeability $\times$ sq. centimeters section $\div$ centimeters length.
- =gilberts $\times$ permeability $\times$ sq. inches section $\times 2.540\ 01 \div$ inches length.
- =gilberts $\times$ sq. centimeters section $\div$ centimeters length. For air.
- =gilberts $\times$ sq. inches section $\times 2.540\ 01 \div$ inches length. For air.
- =gilberts per centimeter $\times$ permeability $\times$ sq. centimeters section.
- =gilberts per inch $\times$ permeability $\times$ sq. inches section $\times 2.540\ 01$.
- =gilberts per centimeter $\times$ sq. centimeters section. For air.
- =gilberts per inch $\times$ sq. inch section $\times 2.540\ 01$. For air.
- =ampere-turns $\times 1.256\ 64\ddagger \div$ oersteds.
- =ampere-turns $\times 1.256\ 64\ddagger \times$ permeance (in CGS units).
- =ampere-turns $\times$ permeability $\times$ sq. centimeters section $\times 1.256\ 64\ddagger \div$ centimeters length.
- =ampere-turns $\times$ permeability $\times$ sq. inches section $\times 3.191\ 86 \div$ inches length.
- =ampere-turns $\times$ sq. centimeters section $\times 1.256\ 64\ddagger \div$ centimeters length. For air.
- =ampere-turns $\times$ sq. inches section $\times 3.191\ 86 \div$ inches length. For air.
- =ampere-turns per centimeter $\times$ permeability $\times$ sq. centimeters section $\times 1.256\ 64\ddagger$.
- =ampere-turns per inch $\times$ permeability $\times$ sq. inches section $\times 3.191\ 86$.
- =ampere-turns per cm $\times$ sq. centimeters section $\times 1.256\ 64\ddagger$. For air.
- =ampere-turns per inch $\times$ sq. inches section $\times 3.191\ 86$. For air.
- =CGS unit current-turns $\times 12.566\ 4\ddagger \div$ oersteds.

(For further relations with CGS unit current-turns, multiply those in terms of ampere-turns by 10; that is, substitute for "ampere-turns" in any of the above, the quantity "CGS unit current-turns $\times 10$.")

Maxwells = volts $\times$ seconds $\times 10^8 \div$ number of turns.

" = volts $\times$ seconds $\times 10^8$. For a single conductor.

When the flux is due only to the current, as in self-induction, and when there is no magnetic leakage:

Maxwells = joules of stored energy $\times 2 \times 10^8 \div$ ampere-turns.

" = joules of stored energy $\times 2 \times 10^8 \div$ amperes. For a single wire.

" = ergs of stored energy $\times 20 \div$ ampere-turns.

" = henrys $\times$ ampere-turns $\times 10^8 \div$ number of turns².

" = henrys $\times$ final amperes $\times 10^8 \div$ number of turns.

When there is magnetic leakage, substitute for "maxwells" in the above, "mean maxwells." The mean maxwells are the mean flux-turns divided by the total number of turns.

When the flux is from an external source, and independent of the current, as in mutual induction, and when there is no magnetic leakage:

Maxwells = joules of stored energy $\times 10^8 \div$ ampere-turns.

" = joules of stored energy $\times 10^8 \div$ amperes. For a single conductor.

" = ergs of stored energy $\times 10 \div$ ampere-turns.

When there is magnetic leakage, make the same substitution as above described.

Mean maxwells (through the secondary):

= henrys (of mutual induction) $\times$ final amperes (of primary) $\times 10^8 \div$ number of turns (of secondary).

$\ddagger$ Or $4\pi/10$. Aprx. add $\frac{1}{4}$. Log 0.099 2099.

$\ddagger$ Or 4π . Aprx. $\frac{1}{8} \times 100$. Log 1.099 2099.

MAGNETIC FLUX DENSITY [$\mathcal{H}$, H]; MAGNETIC INDUCTION [β , B]; LINES OF FORCE PER UNIT CROSS-SECTION; EARTH'S FIELD. (Flux $\div$ surface; magnetizing force $\times$ permeability.)

This quantity, which is one of the most important in magnetic calculations, measures the extent to which a body is magnetized as expressed by the amount of flux which exists per square centimeter (or square inch) of cross-section of the circuit; it gives the density of the flux in C.G.S. units (maxwells or lines of force) per square centimeter or square inch cross-section. It corresponds to current density in electrical calculations. As it specifies or determines the strength of a magnetic field, it is often called the field strength or field intensity;† the earth's magnetic field, for instance, is expressed in these units. When it refers to air it is generally represented by $\mathcal{H}$ or simply H . When it refers to the flux density "induced" in a magnetic material, such as iron, by an outside source, such as a current in a coil of wire, it is often called the **induction**, generally expressed by β or simply by B , which is one of the most important quantities in magnetic calculations. In the calculation and design of dynamos and transformers this induction or flux density in the iron is of prime importance. From it as a starting-point, the size of the core and the required ampere-turns are calculated, as was explained briefly under the units of magnetizing force. The saturation-point of magnetic material like iron is expressed in terms of these units of flux density. The total flux in maxwells is equal to the flux density in gaussess multiplied by the total cross-section in square centimeters. As the permeability or reluctivity of air is unity, it follows that the magnetizing force in gilberts per centimeter of a long coil is numerically the same as the flux density in gaussess produced by it in the interior of the coil, when there is no magnetic material in it. For this reason the magnetizing force is often confused with flux density or its equivalent the intensity of field, as it is then often called. This applies only to the absolute units; when ampere-turns or when inch units are used, a numerical factor must be introduced.

The unit universally used when the dimensions are in the metric system is the **electromagnetic C.G.S. unit**, which, according to the International Congress of 1900, is called a **gauss**. It is defined as that field intensity which is produced at the center of a circle of one centimeter radius by 1 C.G.S. unit of current (or 10 amperes) flowing through an arc of this circle one centimeter long. This is one of the relations which connect the electric with the magnetic units. It can also be defined as the intensity of the field at one centimeter distance from a unit pole, that is, at the surface of a sphere of one centimeter radius, having an imaginary C.G.S. unit pole at its center; from such a pole 4π unit lines of force (maxwells) emanate, and as the area of the sphere is 4π square centimeters, it follows that the flux density will be one line of force or maxwell per square centimeter of the spherical surface. It may also be defined as that field intensity which will exert a pull of one dyne on an (imaginary) isolated unit magnetic pole placed in it. All three of these definitions refer to the same unit. The formulas giving the field intensity in coils, like those for magnets or for galvanometers, all give the result in terms of this unit, provided the current is stated in terms of the absolute unit of current which is equal to 10 amperes; great care must be taken in such formulas to use the proper unit of current; it should always be stated whether the formula has been reduced to amperes or not.

The **practical unit** is therefore the same as the **C.G.S. unit**, namely the **gauss**, which means one maxwell (or line of force) per square centimeter; and a flux density or induction stated in a number of gaussess means that number of maxwells (or lines of force) per square centimeter.

† It should be distinguished, however, from the term intensity of magnetization (see below), which is a term sometimes used in physics and has a different meaning.

When the dimensions are in inches the flux density and induction are often for convenience stated in lines of force (or maxwells) per square inch; this inch unit has no generally accepted name; the name **inch gauss** is here proposed and is used in these tables.

		Logarithm
1 maxwell per sq. inch =	1. inch gauss	0.000 0000
"	= 0.155 000 gauss. Aprx. $\frac{2}{13}$	1.190 3308
1 inch gauss =	1. maxwell per sq. inch	0.000 0000
"	= 0.155 000 gauss. Aprx. $\frac{2}{13}$	1.190 3308
1 CGS unit (elm) =	1. gauss	0.000 0000
1 gauss =	6.451 63 maxwells per sq. inch. Aprx. $1\frac{1}{2}$ or $6\frac{1}{2}$	0.809 6692
"	= 6.451 63 inch gaussess. Aprx. $1\frac{1}{2}$ or $6\frac{1}{2}$	0.809 6692
"	= 1. CGS unit (elm) of flux density	0.000 0000
"	= 1. CGS unit (elm) of flux per sq. centimeter.	0.000 0000
"	= 1. maxwell per sq. centimeter.	0.000 0000
"	= 1. magnetic "line of force" per sq. centimeter.	0.000 0000
1 maxwell per sq. centimeter =	1. gauss.	0.000 0000
1 kilogauss =	1 000. gaussess.	3.000 0000

The relations to other measures are as follows:

Gausses = maxwells $\div$ sq. centimeters.

" = inch gaussess $\times$ 0.155 000.

" = gilberts per centimeter $\times$ permeability.

" = gilberts per inch $\times$ permeability $\times$ 0.393 700.

" = gilberts per centimeter. For air.

" = gilberts per inch $\times$ 0.393 700. For air.

" = gilberts $\times$ permeability $\div$ centimeters.

" = gilberts $\times$ permeability $\times$ 0.393 700 $\div$ inches.

" = gilberts $\div$ centimeters. For air.

" = gilberts $\times$ 0.393 700 $\div$ inches. For air.

" = gilberts $\div$ (oersteds $\times$ sq. centimeters).

" = ampere-turns per centimeter $\times$ permeability $\times$ 1.256 64 $\dagger$.

" = ampere-turns per inch $\times$ permeability $\times$ 0.494 738.

" = ampere-turns per centimeter $\times$ 1.256 64 $\dagger$. For air.

" = ampere-turns per inch $\times$ 0.494 738. For air.

" = ampere-turns $\times$ permeability $\times$ 1.256 64 $\dagger$ $\div$ centimeters.

" = ampere-turns $\times$ permeability $\times$ 0.494 738 $\div$ inches.

" = ampere-turns $\times$ 1.256 64 $\dagger$ $\div$ centimeters. For air.

" = ampere-turns $\times$ 0.494 738 $\div$ inches. For air.

" = ampere-turns $\times$ 1.256 64 $\dagger$ $\div$ (oersteds $\times$ sq. centimeters).

" = CGS unit current-turns per centimeter $\times$ permeability $\times$ 12.566 4 $\dagger$.

(For further relations with CGS unit current-turns, multiply those in terms of ampere-turns by 10; that is, substitute for "ampere-turns" in any of the above, the quantity "CGS unit current-turns $\times$ 10.")

Gausses = volts $\times$ seconds $\times$ $10^8 \div$ (number of turns $\times$ sq. centimeters).

" = CGS units of intensity of magnetization $\times$ 12.566 4 $\dagger$.

Inch gaussess:

= maxwells $\div$ sq. inches.

= gaussess $\times$ 6.451 63.

= gilberts per centimeter $\times$ permeability $\times$ 6.451 63.

= gilberts per inch $\times$ permeability $\times$ 2.540 01.

= gilberts per centimeter $\times$ 6.451 63. For air.

= gilberts per inch $\times$ 2.540 01. For air.

= gilberts $\times$ permeability $\times$ 2.540 01 $\div$ inches.

= gilberts $\times$ 2.540 01 $\div$ inches. For air.

= gilberts $\div$ (oersteds $\times$ sq. inches).

= ampere-turns per centimeter $\times$ permeability $\times$ 8.107 35

= ampere-turns per inch $\times$ permeability $\times$ 3.191 86.

= ampere-turns per centimeter $\times$ 8.107 35. For air.

= ampere-turns per inch $\times$ 3.191 86. For air.

= ampere-turns $\times$ permeability $\times$ 3.191 86 $\div$ inches.

= ampere-turns $\times$ 3.191 86 $\div$ inches. For air.

= ampere-turns $\times$ 1.256 64 $\dagger$ $\div$ (oersteds $\times$ sq. inches).

= CGS unit current-turns per centimeter $\times$ permeability $\times$ 81.073 5.

$\dagger$ Or $4\pi/10$. Aprx. add $\frac{1}{4}$. Log 0.099 2099.

$\dagger$ Or 4π . Aprx. $\frac{1}{8} \times 100$. Log 1.099 2099.

(For further relations with CGS unit current-turns, multiply those in terms of ampere-turns by 10; that is, substitute for "ampere-turns" in any of the above the quantity "CGS unit current-turns $\times 10$.")

Inch gausses = volts $\times$ seconds $\times 10^8 \div$ (number of turns $\times$ sq. inches).

Gausses in iron = gaussses in air $\times$ permeability.

" in air = gaussses in iron $\div$ permeability.

Inch gaussses in iron = inch gaussses in air $\times$ permeability.

" in air = inch gaussses in iron $\div$ permeability.

MAGNETIC MOMENT [M]. (Pole strength $\times$ length.)

This quantity, used chiefly in magnetometry, is the product of the pole strength of a magnet multiplied by its theoretical length, that is, by the distance between the two centers at which the poles may be considered to be condensed. As a pole (see under flux) is not measured in units like force, such a moment is not directly comparable with a mechanical moment called torque, but as the force existing between two unit poles one centimeter apart is one dyne, a magnetic moment may be converted into a mechanical moment. As a single pole has no real existence such a calculation in practice always involves the action of two poles on two others.

There are no special units. The **C.G.S. unit** is a unit pole multiplied by a centimeter, and would therefore be called a **pole-centimeter**. A maxwell-centimeter might also be used, as a unit pole has 4π (=about $12\frac{1}{2}$) maxwells or lines of force issuing from it; each line of force exerts a force of one dyne on a unit pole. Two unit poles one centimeter apart attract or repel each other with a force of one dyne; the force between any two poles is proportional to the product of the two pole strengths in terms of the above unit poles, and inversely proportional to the square of the distance between them in centimeters.

1 unit-pole-centimeter unit = 1. unit pole $\times$ 1. centimeter.

" = 1. CGS unit of magnetic moment.

The relation to other measures are as follows:

Magnetic moments (in CGS units):

= CGS unit poles $\times$ centimeters.

= intensity of magnetization (in CGS units) $\times$ volume in cb. cm.

= gaussses $\times 0.079\ 577\ 5 \times$ volume in cb. cm.

INTENSITY OF MAGNETIZATION [S, I]; MOMENT PER UNIT VOLUME; POLE STRENGTH PER UNIT CROSS-SECTION. (Magnetic moment $\div$ volume; pole strength $\div$ surface.)

This quantity, used chiefly in physical conceptions, measures the polarized state of the interior of a magnet. If a magnet were cut into small pieces (assuming that the magnetic state was not altered thereby) each piece would be a separate magnet whose magnetic moment bears the same proportion to its volume as the moment of the original magnet bears to its volume, hence the magnetic state remains the same if stated in the magnetic moment per cubic centimeter, which quantity is called the intensity of magnetization. It is also the pole strength per square centimeter cross-section. As pole strength is convertible into flux (maxwells), it follows that the intensity of magnetization is a unit of the same nature as flux density, that is, maxwells per square centimeter or gaussses. They differ only in the bases on which they are defined.

The **C.G.S. unit** is one unit moment per cubic centimeter, that is, one unit-pole-centimeter per cubic centimeter, or one unit pole per square centimeter. This unit is numerically equal to 4π gaussses, as its relation to gaussses is the same as the relation of a unit pole is to a unit of flux.

1 CGS unit of intensity of magnetization:

= 1. CGS unit of magnetic moment per cb. centimeter.

= 1. unit-pole-centimeter unit of magnetic moment per cb. cm.

= $12.566\ 4$ (or 4π) gaussses.

The relations to other measures are as follows:

CGS units of intensity of magnetization:

= CGS units of magnetic moments $\div$ cb. centimeters.

= gaussses $\times 0.079\ 577\ 5$.

MAGNETIC WORK or ENERGY [W]. (Magnetomotive force $\times$ flux; ampere-turns $\times$ flux.)

This quantity is seldom used in calculations. When a current is started in a wire or in an electro-magnet, or when the armature of a steel magnet is pulled off, magnetic energy is stored; it is given out again in some other form, often in the form of a spark, when the current is stopped, or as mechanical energy when a permanent magnet attracts its armature to itself. In a transformer, the energy of the primary current is all converted into magnetic energy which is reconverted into electrical energy in the secondary circuit. The magnetic energy is equal to, and in fact is the same thing as, the kinetic energy of a current (which see above). It is equal to the product of magnetomotive force and flux. It appears as heat in the hysteresis loss. It should not be confused with the power used continuously in exciting an electromagnet, as that power is all converted electrically into heat; it is only when the current is first started that any electric energy is converted into magnetic energy. Magnetic flux itself is not energy any more than coulombs of electricity or mechanical pressure; energy is required to produce a pressure, but not necessarily to maintain it, and so it is with magnetic flux (which see above).

There are no specific units of magnetic energy; it is usually measured in joules or ergs, but may be measured in terms of any of the units of energy, which see. The C.G.S. unit is the erg; the practical unit is the joule.

The relations to other measures are as follows:

Joules of magnetic energy [J]:

- = henrys $\times$ final amperes² $\div$ 2.
- = henrys $\times$ applied volts² $\div$ (ohms² $\times$ 2).
- = time constant in seconds $\times$ ohms $\times$ final amperes² $\div$ 2.
- = time constant in seconds $\times$ final amperes $\times$ applied volts $\div$ 2.
- = time constant in seconds $\times$ applied volts² $\div$ (ohms $\times$ 2).

When the flux is due only to the current, as in self-induction, and when there is no magnetic leakage:

Joules of magnetic energy:

- = maxwells $\times$ ampere-turns $\div$ (2×10^8).
- = gaussses $\times$ sq. centimeters $\times$ ampere-turns $\div$ (2×10^8).
- = inch-gaussses $\times$ sq. inches $\times$ ampere-turns $\div$ (2×10^8).
- = maxwells² $\times$ oersteds $\times$ 0.397 887 $\div$ 10^8 .
- = maxwells $\times$ gilberts $\times$ 0.397 887 $\div$ 10^8 .
- = gilberts² $\times$ 0.397 887 $\div$ (oersteds $\times$ 10^8).
- = ampere-turns² $\times$ permeability $\times$ sq. centimeter section $\times$ 0.628 318 (or $2\pi/10$) $\div$ (centimeters length $\times$ 10^8).
- = ampere-turns² $\times$ permeability $\times$ sq. inches section $\times$ 1.595 93 $\div$ inches length $\times$ 10^8 .

(For further relations substitute for any of the above units their equivalents in terms of the desired units, as given in the other tables.)

When the flux is from an external source and independent of the current, as in mutual induction, and when there is no magnetic leakage, the magnetic energy is twice as great as that given by the above relations; hence all the values above given must be multiplied by 2.

When there is magnetic leakage, use the "mean maxwells" instead of the "maxwells." The mean maxwells are the mean flux turns divided by the total number of turns.

Ergs of magnetic energy = henrys $\times$ final amperes² $\times$ 5×10^6 .

(For further relations of ergs to other units multiply those given above for joules by 10^7 .)

MAGNETIC POWER [P]. (Magnetomotive force $\times$ flux $\div$ time; ampere-turns $\times$ flux $\times$ frequency.)

This quantity is seldom used in calculations, and has little or no significance in practice. It is the rate at which magnetic work or energy is performed (see Magnetic Energy above); it is therefore equal to magnetic energy divided by time. It is met with in practice in the alternating magnetic fields of alternating electric currents, for in these the magnetic field is continually being produced at a rate proportional to the frequency, hence it is proportional to the product of the magnetomotive force, the flux, and the frequency. The power of the primary current in a transformer is transmitted to the secondary in the form of magnetic power, part of it being lost as magnetic power in the form of hysteresis.

With alternating magnetic fluxes the magnetic energy stored by the current when flowing in one direction, is in many cases returned to the circuit again when the current is flowing in the reversed direction; it surges to and fro in the iron, being alternately positive and negative, like in a spring which is alternately compressed and released; hence calculations of the amount of the magnetic power involved are generally of no importance in practice. Whatever energy leaves the circuit is generally in the form of electrical energy (as in transformers) or heat (as in the hysteresis loss); in such cases the power of this energy in watts is equal to the amount in joules which leaves per cycle, multiplied by the frequency.

There are no specific units of magnetic power; such power is usually measured in watts or in ergs per second, but it may be measured in terms of any of the units of power. The C.G.S. unit is the erg per second; the practical unit is the watt.

The relations to other measures are as follows:

Watts of magnetic power [W, w] = henrys $\times$ final amperes² $\div$ seconds $\times$ 2.

(For further relations divide any of the values given for "joules," in the preceding section, by "seconds.")

PHOTOMETRIC UNITS.

The different kinds or units or measures given below and their relations and symbols (except "*cp*" for candle-power) are those adopted by the unofficial International Congress at Geneva in 1896.

INTENSITY OF LIGHT [I]; CANDLE POWER [cp].
(Flux of light $\div$ solid angle; power $\div$ solid angle.)

This quantity, which is the one most frequently used in photometry, measures the intensity of a source of light in any one direction. For the same total quantity or flux of light radiating from a source, the intensity in any one direction becomes less as the solid angle through which it is radiated becomes greater, hence the intensity is the total flux (in lumens) divided by the number of units of solid angle (see under the table of units of Solid Angles, p. 89).

There have been introduced from time to time various standards to be used as reproducible units of the intensity of light, all of which are at best only crude approximations to an exact standard. The most reliable of these, and the one which is being generally accepted and is coming into use internationally, is the **hefner unit**, an amyl acetate lamp of fixed dimensions and height of flame. It has been carefully investigated by the

Reichsanstalt and its coefficients have been determined; it was recommended for international adoption to the International Electrical Congress at Chicago in 1893, but was not adopted for reasons which probably do not exist now; it has been adopted by the Reichsanstalt; it has also been accepted tentatively by the National Bureau of Standards through incandescent lamp secondary standards measured in terms of it at the Reichsanstalt; it is endorsed by the American Institute of Electrical Engineers.

The hefner standard lamp is very fully described with diagrams in an article emanating from the Reichsanstalt, published in the *Zeitschrift für Instrumentenkunde*, Vol. XIII, July, 1893, p. 257. In this article the hefner unit is defined as the amount of light from a flame burning free in stationary pure air, from a thick wick saturated with amyl acetate, the wick completely filling a circular wick-tube of German silver, the inner diameter of the tube being 8 mm, and the outer diameter 8.3 mm, the free length of this tube being 25 mm; the height of flame is 40 mm from the edge of the wick-tube, measured at least 10 minutes after lighting.

The relation " $1 \text{ hefner} = 0.88 \text{ British standard candle}$ " is the one generally used; it is the relation adopted by the Reichsanstalt and is the one used by the National Bureau of Standards.

The next most important standard is the **British standard candle** or **English spermaceti candle** or simply **English candle**, which is about $13\frac{1}{2}\%$ greater than the hefner. The definition of the English candle used by the National Bureau of Standards is the relation $1 \text{ hefner} = 0.88 \text{ English candles}$. This standard is the one universally referred to in this country by the large incandescent electric lamp manufacturers and gas companies, under the term "**candle power**." The candle itself is not as easy to use nor as reliable or constant as the hefner, for which reason the hefner is generally used as the ultimate standard, the results being subsequently reduced to such English candles by the relation $1 \text{ hefner} = 0.88 \text{ of these candles}$. An official specification of the British standard candle is given very fully in an article in the *American Gas Light Journal*, 1894, Jan. 8th, p. 41. The candle has a special wick, is made of spermaceti mixed with 3% to $4\frac{1}{2}\%$ of bleached beeswax, weighs about a sixth of a pound, and must burn at a rate not greater than 126 or less than 114 grains per hour. In the comparisons made by the Reichsanstalt with the hefner, the height of the flame of this English standard candle was 45 mm.

The unit called the **platinum standard of light**, sometimes improperly called an **absolute unit**, is the light emitted perpendicularly from a square centimeter of surface of melted platinum at the temperature of its solidification. It is often called the **violle**. This was virtually adopted by an International Congress, but never came into use, and seems to have been abandoned. Its value is not known definitely, but is approximately 20 candles. The **bougie décimale**, sometimes called a **pyr**, is one twentieth of this, and at the unofficial Geneva Congress of 1896 its value was provisionally considered to be represented in practice by one hefner. This is the value which will be used in the following tables.

The **German paraffin candle** has gone out of use, being replaced by the hefner.

The **carcel** is an oil lamp formerly largely used as a standard in France; the oil is kept at a fixed level by means of a pump driven by clockwork.

The **Harcourt pentane lamp** is a flame using pentane gas; it is generally made for 1 and for 10 candle-power; it is used extensively as a secondary standard and as such seems to be satisfactory, but each lamp must be calibrated by comparison with some standard, as it seems they cannot be made sufficiently uniform to have a definite value like the hefner.

Standard incandescent electric lamps which have been very carefully standardized by means of the hefner lamp as the ultimate standard, can now be purchased for use as standards. When their voltage is carefully adjusted, which can be done with great accuracy, they form very satisfactory standards and are said to be very reliable. They are used quite extensively and are probably the best form of secondary standards when a constant source of electric current is available.

Probably the best collection of values of the various standards is that in a paper by Dr. Bunte in "The Technical Standards of Light," read before the International Photometry Committee in June, 1903. It is translated in the *Journal of Gas-lighting*, June 30, 1903, also in the *Progressive Age*, Sept. 1 and 15, 1903. In the following table those values for which the authority is given as Bunte, have been taken from this paper.

The following values, which are believed to be the best obtainable, are mostly only approximate; different authorities do not agree.

**** Means accepted by the Reichsanstalt and the National Bureau of Standards. The names in parenthesis are the authorities.**

1 hefner = 1. bougie décimale. (Geneva Congress.)
 = 1.026 bougies décimales. (Violle.)
 = 0.89 bougie décimale. (Bunte.)
 = 0.885 bougie décimale. (Laporte.)
 = 0.833 German candle. (Bunte.)
 = **0.88**** British or English standard candle (universally accepted value). Aprx. $\frac{7}{8}$.
 = 0.092 carcel. (Bunte.)

1 bougie décimale :

= 1 hefner. (Geneva Congress.)
 = 1.13 hefners. (Violle.)
 = 0.88 British or English standard candle. (1 hefner = 0.88 candle.)
 = 0.99 British or English standard candle. (Violle.)
 = 0.94 German candle. (Violle.)
 = **0.05 violle.** (Official.)

1 pyr = 1 bougie décimale.

1 British or English standard candle [cp]:

= 1.136 36 hefners (from the accepted value of the hefner). Aprx. $\frac{8}{9}$.
 = 1.14 hefners. (Bunte.)
 = 1.01 bougies décimales. (Bunte.)
 = 0.950 German candle. (Bunte.)
 = 0.105 carcel. (Bunte.)

1 candle or candle power [cp]:

= in this country and England 1 British or English standard candle.

1 German paraffin candle (20 mm diam.):

= 1.224 hefners. (German Gas and Water Committee.)
 = 1.20 hefners. (Bunte.)
 = 1.16 hefners. (Lummer and Brodhun.)
 = 1.05 English candles. (Bunte.)
 = 1.07 bougies décimales.
 = 1.05 bougies décimales. (Laporte.)
 = 0.110 carcel. (Bunte.)

1 carcel = 10.87 hefners. (Bunte.)

" = 10.9 hefners.
 " = 9.62 bougies décimales. (Violle.)
 " = 9.53 English candles. (Bunte.)
 " = 9.05 German candles. (Bunte.)
 " = 0.481 violle. (Violle.)

1 violle = 22.6 hefners. (Violle.)

" = 20. bougies décimales. (Official.)
 " = 20. hefners. (Geneva Congress.)
 " = 19.8 English candles. (Violle.)
 " = 18.8 German candles. (Violle.)
 " = 2.08 carrels. (Violle.)

1 platinum standard = 1 violle. (Official.)

1 absolute unit = 1 violle.

1 Harcourt pentane lamp :

= secondary standard made for various candle-powers.

In the following relations a candle means a hefner unit.

Candles = lumens $\div$ units solid angle.

" = luxes $\times$ (distance in meters)².

" = units of brightness $\times$ sq. centimeters.

" = lumen-hours $\div$ (units solid angle $\times$ hours).

FLUX OF LIGHT $[\Phi]$; SPHERICAL OR HEMI-SPHERICAL CANDLE POWER. (Candle power $\times$ solid angle; power.)

This quantity measures the whole radiation or whole beam of light, and is therefore equal to the intensity in candle powers multiplied by the number of units of solid angle through which the conical beam radiates. In practice the solid angles more usually used are either the hemisphere ($=6.283\ 19$ units) or the whole sphere ($=12.566\ 4$ units). This quantity, being a radiation of energy, is of the same nature as power, and a relation between the two should exist and would be called the mechanical equivalent of light but it is not yet known; it is believed to be of the order of about 5.3 spherical candles per watt or 0.188 watts per spherical candle.†

The unit of flux is the amount of flux of light in a beam of one unit solid angle (one which subtends a square centimeter at a radius of one centimeter) in which the intensity is one candle power. The name of this unit adopted by the Geneva Congress is **lumen**. In practice the units **spherical candle power** and **hemispherical candle power** are often used instead, referring in this country and England to the English candle.

In each of the following conversion factors the flux is the same, but the solid angle within which it is confined is different. Aprx. means within 2%.

- 1 lumen = 1. solid angle hefner.
 " = 0.159 155 hemispherical hefner. Aprx. $16 \div 100$.
 " = 0.140 036 hemispherical (English) candle power. Aprx. $\frac{1}{4}$.
 " = 0.079 577 spherical hefner. Aprx. $8 \div 100$.
 " = 0.070 028 spherical (English) candle power. Aprx. $7 \div 100$.

- 1 hemispherical hefner:
 = 6.283 19 lumens. Aprx. $6\frac{1}{4}$.
 = 0.88 hemispherical (English) candle power. Aprx. $\frac{3}{8}$.
 = 0.500 000 spherical hefner.
 = 0.440 000 spherical (English) candle power. Aprx. $\frac{4}{9}$.

- 1 hemispherical (English) candle power:
 = 7.139 99 lumens. Aprx. $5\frac{1}{4}$.
 = 1.136 36 hemispherical hefners. Aprx. $\frac{8}{7}$.
 = 0.568 181 spherical hefner. Aprx. $\frac{4}{7}$.
 = 0.500 000 spherical (English) candle power.

- 1 spherical hefner:
 = 12.566 4 lumens. Aprx. $\frac{1}{8} \times 100$.
 = 1.76 hemispherical (English) candle powers. Aprx. $\frac{7}{4}$.
 = 2 hemispherical hefners.
 = 0.88 spherical (English) candle power. Aprx. $\frac{3}{8}$.

- 1 spherical (English) candle power:
 = 14.280 0 lumens. Aprx. $\frac{1}{7} \times 100$.
 = 2.272 73 hemispherical hefners. Aprx. $\frac{9}{4}$.
 = 2 hemispherical (English) candle powers.
 = 1.136 36 spherical hefners. Aprx. $\frac{8}{7}$.

In the following relations one candle means a hefner unit

- Lumens = candles $\times$ units solid angle.
 " = candles $\times$ sq. meters of illuminated surface $\div$ (distance in meters)².
 " = luxes $\times$ surface in sq. meters.
 " = units of brightness $\times$ surface in sq. cm $\times$ units solid angle.
 " = lumen-hours $\div$ hours.

† See Mechanical Equivalent of Light. *Elec. World and Eng.*, April 20, 1901, p 631.

ILLUMINATION [E]. (Candle power $\div$ distance²; flux of light $\div$ surface.)

This quantity measures the amount of light falling on a surface; it measures that which is received as distinguished from that which is given out by the source. It is a very important quantity in photometry, as illumination is that which light is intended to produce. The illumination of a surface is proportional to the candle power of the source of light and inversely proportional to the square of the distance of the illuminated surface from the source; if the intensity of the source is in hefners and the distance in meters, then the illumination will be in luxes. The illumination in luxes is also equal to the total flux of light in lumens shining on the surface, divided by the amount of the surface in square meters. These relations give the amount of illumination which reaches that surface from the source, and not the amount of light reflected from the surface, as that depends on the nature and color of the surface.

The unit adopted by the Geneva Congress is a **lux**, which is equal to the illumination produced by one hefner at a distance of one meter. When the source is called a candle, then this unit is often called a **meter-candle**; but it is then improperly named, as it should be called a **candle per meter** or still more correctly a **candle per meter squared**. The lux is also equal to one lumen of flux per square meter. A unit called the **foot-candle** (more properly **candle per foot** or **candle per foot squared**) is also used; it is equal to the illumination produced by an English candle at a distance of one foot. With these units the amount of light required to produce any desired illumination at a given distance can readily be calculated.

1 lux:

- = 1. lumen per sq. meter.
- = 1. meter-candle (hefner) or 1 candle (hefner) per meter squared.
- = 0.081 8 foot-candle (English) or candle (English) per foot squared.

Aprx. $\frac{1}{12}$.

1 meter-candle (hefner):

- = 1. lux.
- = 1. lumen per sq. meter.
- = 0.081 8 foot-candle (English). Aprx. $\frac{1}{12}$.

1 foot-candle (English) = 12.2 luxes.

- " = 12.2 meter-candles (hefner).
- " = 12.2 lumens per sq. meter.

In the following relations a candle means a hefner unit.

Luxes = candles $\div$ (distance in meters)².

" = flux in lumens $\div$ surface in sq. meters.

" = flux in lumens $\div$ [(distance in meters)² $\times$ units solid angle].

" = candles $\times$ units solid angle $\div$ surface in sq. meters.

" = units of brightness $\times$ surface of source in sq. cm. $\div$ (dist. in meters)².

" = lumen-hours $\div$ (hours $\times$ surface in sq. meters).

BRIGHTNESS OF SOURCE [e]. (Candle power $\div$ surface of source.)

This quantity measures the brightness of the source; it is the total candle power of the source divided by its surface in sq. centimeters. It is seldom used. The unit is **one hefner per sq. centimeter**; no name has been given to it. As there are no other units of this kind, there are no conversion factors.

1 unit of brightness = 1 candle (hefner) per sq. centimeter.

In the following relations a candle means a hefner unit.

Units of brightness:

= candles $\div$ centimeter².

= flux in lumens $\div$ (centimeter² $\times$ units solid angle).

QUANTITY OF LIGHT [Q]. (Flux of light $\times$ time; energy.)

This quantity measures the total amount or volume of light together with its duration. A rational payment for light, for instance, would be made in terms of this unit. It is equal to the amount of flux in lumens multiplied by the time in hours.

The unit is one lumen of flux for one hour, and is called a **lumen-hour**. As there are no other units of the same kind, there are no conversion factors.

1 lumen-hour = 1 lumén for one hour.

In the following relations a candle means a hefner unit.

Lumen-hours:

- = flux in lumens $\times$ hours.
- = candles $\times$ hours $\times$ units solid angle.
- = candles $\times$ illuminated surface in sq. meters $\times$ hours $\div$ (distance in meters)².
- = luxes $\times$ illuminated surface in sq. meters $\times$ hours.
- = units of brightness $\times$ sq. cm of source $\times$ units solid angle $\times$ hours.
- = units of brightness $\times$ sq. cm of source $\times$ illuminated surface in sq. meters $\times$ hours $\div$ (distance in meters)².

LIGHT EFFICIENCY; POWER PER CANDLE POWER. (Candles $\div$ power; power $\div$ candles.)

The efficiencies of electric lights are frequently compared with each other by comparing the watts required per candle. The number thus obtained, by dividing the watts by the candles, is sometimes called the efficiency, which term, however, is incorrectly used, because the greater the watts per candle, the lower the efficiency; the term efficiency would be more correctly applied to the number giving the candles per watt. Comparisons between such relative efficiencies are very useful, even though the figures are not the absolute efficiencies; for the latter it would be necessary to know the mechanical equivalent of light,[†] and instead of the candle power, the total flux in lumens or the spherical candle powers should be used, so as to include the solid angle through which the light is radiated.

The following relations apply equally well to hefners as to English candles.

n watts per candle = $1/n$ candles per watt.

n candles per watt = $1/n$ watts per candle.

n watts per candle = $735.448/n$ candles per metric horse-power.

" = $745.650/n$ candles per horse-power.

" = $1\,000/n$ candles per kilowatt.

n candles per metric horse-power = $735.448/n$ watts per candle.

n candles per horse-power = $745.650/n$ watts per candle.

n candles per kilowatt = $1\,000/n$ watts per candle.

For the relation between watts, horse-powers, etc., see table of units of Power, page 80.

[†] See notes on Flux of Light, p. 147, and the foot-note.

THERMOMETER SCALES.

Of the four scales in use, the **Centigrade** scale (also called **Celsius**) is the most rational one and the one used in all scientific research and international literature; it is also used exclusively in some of the European countries. The zero point is the melting point of ice, and the 100° point is the boiling point of water. The **Fahrenheit** scale is used in the United States and England; on this scale the melting point of ice is exactly 32° and the boiling point of water is 212° . The **Réaumur** scale is in limited use in Germany; it has the same zero point as the Centigrade scale, but the boiling point of water on this scale is exactly 80° . The **Absolute** scale begins at a theoretical, assumed point, supposed at present to be the lowest temperature which can exist; this point is calculated from the expansion of gases at ordinary temperatures and it is assumed that the same law holds good down to an absolute zero; it has never been reached, but has been approached to within 17 degrees of the Centigrade scale.

The following table gives the corresponding values on these four different scales for the complete range of all known temperatures, thus avoiding most of the reductions. To these has been added a "concrete scale," which gives numerous temperatures at which certain materials change some property, thereby enabling one to establish, maintain, or measure those temperatures. But as most of these temperatures are not known definitely, they cannot be relied upon for more than approximate correctness. They have been compiled from a large number of sources with due regard for the authorities; many of them were taken from Carnelley's excellent table of melting and boiling points, and from Landolt and Boernstein's tables.

Reduction factors for one degree:

A **Centigrade degree** is $\frac{9}{5}$ or 1.8 Fahrenheit degrees. It is $\frac{4}{5}$ or 0.8 Réaumur degree. It is the same as a degree of the Absolute scale.

A **Fahrenheit degree** is $\frac{5}{9}$ or a little more than half of a Centigrade degree or of a degree of the Absolute scale. It is $\frac{4}{9}$ of a Réaumur degree.

A **Réaumur degree** is $\frac{5}{4}$ or 1.25 Centigrade degrees, or degrees of the Absolute scale. It is $\frac{9}{4}$ or 2.25 Fahrenheit degrees.

A **degree of the Absolute scale** is the same as of the Centigrade scale.

Reduction factors for readings of a temperature in degrees:

To convert a **reading in Centigrade degrees** into the corresponding one in Fahrenheit degrees, multiply by $\frac{9}{5}$ and add 32. To convert it into the one in Réaumur degrees multiply by $\frac{4}{5}$. To convert it into the one on the Absolute scale, add 273.

To convert a **reading in Fahrenheit degrees** into the one in Centigrade degrees, subtract 32 and then multiply by $\frac{5}{9}$, being careful about the signs when the reading is below the melting point of ice. To convert it into the one in Réaumur degrees, subtract 32 and multiply by $\frac{4}{9}$. To convert it into the one on the Absolute scale, subtract 32, then multiply by $\frac{5}{9}$ and add 273; or multiply by 5, add 2297, and divide by 9.

To convert a **reading in Réaumur degrees** into the one in Centigrade degrees, multiply by $\frac{5}{4}$. To convert it into the one in Fahrenheit degrees, multiply by $\frac{9}{4}$ and add 32. To convert it into the one on the Absolute scale, multiply by $\frac{5}{4}$ and add 273.

To convert a **reading on the Absolute scale** to the one in Centigrade degrees, subtract 273. To convert it into the one in Fahrenheit degrees subtract 273, multiply by $\frac{9}{5}$, and add 32; or multiply by 9, subtract 2297, and divide by 5. To convert it into the one in Réaumur degrees subtract 273 and multiply by $\frac{4}{5}$.

All these reduction factors are strictly correct. Care must be taken to add or subtract *algebraically* when any of the readings are below the zero of the respective scale, in which case they should be preceded by the negative sign. There can be no negative values on the Absolute scale (unless it is shown in the future that the absolute zero has been fixed too high, a possibility which may not be remote).

THERMOMETER SCALES.

Centi- grade Deg.	Fahren- heit Deg.	Réau- mur Deg.	Abso- lute Deg.	Concrete Scale (mostly only approximate).
-273	-459.4	-218.4	0	-256° C. hydrogen freezes
-250	-418.0	-200.0	+ 23	-250° C. hydrogen boils
-225	-373.0	-180.0	+ 48	-214° C. nitrogen freezes
-200	-328.0	-160.0	+ 73	-200° C. temperature of liquid air
-190	-310.0	-152.0	+ 83	-193.1° to -194° C. (760 mm press.) nitro- [gen boils
-180	-292.0	-144.0	+ 93	-181.4° to -184° C. (1 atm.) oxygen boils
-170	-274.0	-136.0	+103	-167.0° C. nitric oxide solidifies
-160	-256.0	-128.0	+113	
-150	-238.0	-120.0	+123	-153.6° C. nitric oxide boils
-140	-220.0	-112.0	+133	
-130	-202.0	-104.0	+143	-130.5° C. pure ethyl alcohol freezes
-120	-184.0	- 96.0	+153	
-110	-166.0	- 88.0	+163	-112.5° C. hydrochloric acid melts
-100	-148.0	- 80.0	+173	-102° C. hydrochloric acid condenses
- 90	-130.0	- 72.0	+183	-85.5° C. hydrogen sulphide solidifies
- 80	-112.0	- 64.0	+193	-76° C. sulphur dioxide solidifies
- 70	- 94.0	- 56.0	+203	-75° C. ammonia melts
- 60	- 76.0	- 48.0	+213	-61.8° C. hydrogen sulphide boils at 760 [mm
- 50	- 58.0	- 40.0	+223	[sol.] solidifies
- 45	- 49.0	- 36.0	+228	-38° to -41° C. ammonium hydrate (sat.)
- 40	- 40.0	- 32.0	+233	-39.5° C. mercury melts
- 35	- 31.0	- 28.0	+238	-33.7° C. ammonia boils
- 30	- 22.0	- 24.0	+243	-33.6° C. chlorine boils
- 28	- 18.4	- 22.4	+245	
- 26	- 14.8	- 20.8	+247	
- 24	- 11.2	- 19.2	+249	
- 22	- 7.6	- 17.6	+251	
- 20	- 4.0	- 16.0	+253	-20.7° C. (CN) ₂ boils
- 19	- 2.2	- 15.2	+254	
- 18	- 0.4	- 14.4	+255	-18.0° C. SbH ₃ boils
-17.8	0	- 14.2	+255.2	
-17.2	+ 1.0	- 13.8	+255.8	
-17.0	+ 1.4	- 13.6	+256.0	
-16.7	+ 2.0	- 13.3	+256.3	
-16.1	+ 3.0	- 12.9	+256.9	
-16.0	+ 3.2	- 12.8	+257.0	
-15.6	+ 4.0	- 12.4	+257.4	
-15.0	+ 5.0	- 12.0	+258.0	
-14.4	+ 6.0	- 11.6	+258.6	
-14.0	+ 6.8	- 11.2	+259.0	
-13.9	+ 7.0	- 11.1	+259.1	
-13.3	+ 8.0	- 10.7	+259.7	
-13.0	+ 8.6	- 10.4	+260.0	
-12.8	+ 9.0	- 10.2	+260.2	
-12.2	+10.0	- 9.8	+260.8	
-12.0	+10.4	- 9.6	+261.0	
-11.7	+11.0	- 9.3	+261.3	
-11.1	+12.0	- 8.9	+261.9	
-11.0	+12.2	- 8.8	+262.0	
-10.6	+13.0	- 8.4	+262.4	-10.5° C. sulphur dioxide boils at 744 mm

THERMOMETER SCALES—(Continued).

Centi- grade Deg.	Fahren- heit Deg.	Réau- mur Deg.	Abso- lute Deg.	Concrete Scale (mostly only approximate).
-10.0	+14.0	-8.0	+263.0	
-9.4	+15.0	-7.6	+263.6	
-9.0	+15.8	-7.2	+264.0	
-8.9	+16.0	-7.1	+264.1	
-8.3	+17.0	-6.7	+264.7	-8.5° C. sulphuric acid melts, sp. gr. 1.732
-8.0	+17.6	-6.4	+265.0	
-7.8	+18.0	-6.2	+265.2	-7.5° C. sulphuric acid melts, sp. gr. 1.727
-7.2	+19.0	-5.8	+265.8	-7.2° C. bromine solidifies
-7.0	+19.4	-5.6	+266.0	
-6.7	+20.0	-5.3	+266.3	
-6.1	+21.0	-4.9	+266.9	
-6.0	+21.2	-4.8	+267.0	
-5.6	+22.0	-4.4	+267.4	
-5.0	+23.0	-4.0	+268.0	
-4.4	+24.0	-3.6	+268.6	
-4.0	+24.8	-3.2	+269.0	
-3.9	+25.0	-3.1	+269.1	
-3.3	+26.0	-2.7	+269.7	
-3.0	+26.6	-2.4	+270.0	
-2.8	+27.0	-2.2	+270.2	
-2.2	+28.0	-1.8	+270.8	
-2.0	+28.4	-1.6	+271.0	
-1.7	+29.0	-1.3	+271.3	
-1.1	+30.0	-0.9	+271.9	
-1.0	+30.2	-0.8	+272.0	
-0.6	+31.0	-0.4	+272.4	
0	+32.0	0	+273.0	0° C. freezing point of water
+0.6	+33.0	+0.4	+273.6	
1.0	33.8	0.8	274.0	
1.1	34.0	0.9	274.1	
1.7	35.0	1.3	274.7	
2.0	35.6	1.6	275.0	
2.2	36.0	1.8	275.2	
2.8	37.0	2.2	275.8	
3.0	37.4	2.4	276.0	3° C. benzene (benzol) freezes
3.3	38.0	2.7	276.3	
3.9	39.0	3.1	276.9	
4.0	39.2	3.2	277.0	[molecular proportion melts
4.4	40.0	3.6	277.4	4.5° C. alloy of potassium and sodium in
5.0	41.0	4.0	278.0	4.5° C. sulphuric acid melts, sp. gr. 1.749
5.6	42.0	4.4	278.6	
6.0	42.8	4.8	279.0	6° C. alloy of 1 potassium and 1 sodium
6.1	43.0	4.9	279.1	[melts
6.7	44.0	5.3	279.7	
7.0	44.6	5.6	280.0	
7.2	45.0	5.8	280.2	
7.8	46.0	6.2	280.8	
8.0	46.4	6.4	281.0	
8.3	47.0	6.7	281.3	
8.9	48.0	7.1	281.9	

THERMOMETER SCALES—(Continued).

Centi- grade Deg.	Fahren- heit Deg.	Réau- mur Deg.	Absol- ute Deg.	Concrete Scale (mostly only approximate).
9.0	48.2	7.2	282.0	10.5° C. pure sulphuric acid freezes, sp. gr. [1.854]
9.4	49.0	7.6	282.4	
10.0	50.0	8.0	283.0	
10.6	51.0	8.4	283.6	
11.0	51.8	8.8	284.0	
11.1	52.0	8.9	284.1	
11.7	53.0	9.3	284.7	17° C. pure acetic acid freezes
12.0	53.6	9.6	285.0	
12.2	54.0	9.8	285.2	
12.8	55.0	10.2	285.8	
13.0	55.4	10.4	286.0	
13.3	56.0	10.7	286.3	
13.9	57.0	11.1	286.9	19°–20° C. fresh butter solidifies
14.0	57.2	11.2	287.0	
14.4	58.0	11.6	287.4	
15.0	59.0	12.0	288.0	
15.6	60.0	12.4	288.6	
16.0	60.8	12.8	289.0	
16.1	61.0	12.9	289.1	20°–20.5° C. cocoanut oil solidifies
16.7	62.0	13.3	289.7	
17.0	62.6	13.6	290.0	
17.2	63.0	13.8	290.2	
17.8	64.0	14.2	290.8	
18.0	64.4	14.4	291.0	
18.3	65.0	14.7	291.3	20.5° C. cocoa butter solidifies
18.9	66.0	15.1	291.9	
19.0	66.2	15.2	292.0	
19.4	67.0	15.6	292.4	
20.0	68.0	16.0	293.0	
20.6	69.0	16.4	293.6	
21.0	69.8	16.8	294.0	21° C. fresh soft palm oil solidifies
21.1	70.0	16.9	294.1	
21.7	71.0	17.3	294.7	
22.0	71.6	17.6	295.0	
22.2	72.0	17.8	295.2	
22.8	73.0	18.2	295.8	
23.0	73.4	18.4	296.0	24° C. fresh hard palm oil solidifies
23.3	74.0	18.7	296.3	
23.9	75.0	19.1	296.9	
24.0	75.2	19.2	297.0	
24.4	76.0	19.6	297.4	
25.0	77.0	20.0	298.0	
25.6	78.0	20.4	298.6	24.5° C. cocoanut oil melts
26.0	78.8	20.8	299.0	
26.1	79.0	20.9	299.1	
26.7	80.0	21.3	299.7	
27.0	80.6	21.6	300.0	
27.2	81.0	21.8	300.2	
27.8	82.0	22.2	300.8	26.5° C. pure hydrocyanic acid boils
28.0	82.4	22.4	301.0	

THERMOMETER SCALES—(Continued).

Centi- grade Deg.	Fahren- heit Deg.	Réau- mur Deg.	Abso- lute Deg.	Concrete Scale (mostly only approximate).
28.3	83.0	22.7	301.3	28.5° C. calcium chloride, ($\text{CaCl}_2 + 6\text{H}_2\text{O}$), [melts (see also under 719° C.)]
28.9	84.0	23.1	301.9	
29.0	84.2	23.2	302.0	
29.4	85.0	23.6	302.4	30° C. lard solidifies
30.0	86.0	24.0	303.0	30° C. fresh soft palm oil melts
30.6	87.0	24.4	303.6	30° C. gallium melts
31.0	87.8	24.8	304.0	
31.1	88.0	24.9	304.1	31°–31.5° C. fresh butter melts
31.7	89.0	25.3	304.7	
32.0	89.6	25.6	305.0	
32.2	90.0	25.8	305.2	
32.8	91.0	26.2	305.8	
33.0	91.4	26.4	306.0	33° C. nutmeg butter solidifies
33.3	92.0	26.7	306.3	33° C. fresh beef tallow solidifies
33.9	93.0	27.1	306.9	33.5°–34° C. cocoa butter melts
34.0	93.2	27.2	307.0	34° C. old beef tallow solidifies
34.4	94.0	27.6	307.4	34.5° C. ether boils
35.0	95.0	28.0	308.0	
35.6	96.0	28.4	308.6	
36.0	96.8	28.8	309.0	36° C. fresh mutton tallow solidifies
36.1	97.0	28.9	309.1	
36.7	98.0	29.3	309.7	
37.0	98.6	29.6	310.0	37° C. blood heat of the human body
37.2	99.0	29.8	310.2	
37.8	100.0	30.2	310.8	38° C. fresh hard palm oil melts
38.0	100.4	30.4	311.0	38° C. old palm oil solidifies
38.3	101.0	30.7	311.3	38° C. pentane boils
38.9	102.0	31.1	311.9	38.5° C. rubidium melts
39.0	102.2	31.2	312.0	39.5° C. old mutton tallow solidifies
39.4	103.0	31.6	312.4	39.5° C. crystalline phenol (carbolic acid) [melts]
40.0	104.0	32.0	313.0	40° C. magnesium chlorate melts
40.6	105.0	32.4	313.6	40.5°–41° C. Japanese wax solidifies
41.0	105.8	32.8	314.0	
41.1	106.0	32.9	314.1	
41.7	107.0	33.3	314.7	41.5°–42° C. lard melts
42.0	107.6	33.6	315.0	42° C. old palm oil melts
42.2	108.0	33.8	315.2	
42.8	109.0	34.2	315.8	
43.0	109.4	34.4	316.0	43° C. fresh beef tallow melts
43.3	110.0	34.7	316.3	43.5° C. old beef tallow melts
43.9	111.0	35.1	316.9	43.5°–44° C. nutmeg butter melts
44.0	111.2	35.2	317.0	44° C. spermaceti solidifies
44.4	112.0	35.6	317.4	44°–44.5° C. spermaceti melts
45.0	113.0	36.0	318.0	44.2°–44.5° C. yellow phosphorus melts
45.6	114.0	36.4	318.6	
46.0	114.8	36.8	319.0	
46.1	115.0	36.9	319.1	
46.7	116.0	37.3	319.7	
47.0	116.6	37.6	320.0	47° C. fresh mutton tallow melts
47.2	117.0	37.8	320.2	

THERMOMETER SCALES—(Continued).

Centi- grade Deg.	Fahren- heit Deg.	Réau- mur Deg.	Abso- lute Deg.	Concrete Scale (mostly only approximate).
47.8	118.0	38.2	320.8	
48.0	118.4	38.4	321.0	
48.3	119.0	38.7	321.3	
48.9	120.0	39.1	321.9	
49.0	120.2	39.2	322.0	
49.4	121.0	39.6	322.4	
50.0	122.0	40.0	323.0	50° C. hydrogen perchlorate melts
50.6	123.0	40.4	323.6	50.5° C. old mutton tallow melts
51.0	123.8	40.8	324.0	
51.1	124.0	40.9	324.1	
51.7	125.0	41.3	324.7	
52.0	125.6	41.6	325.0	
52.2	126.0	41.8	325.2	
52.8	127.0	42.2	325.8	
53.0	127.4	42.4	326.0	
53.3	128.0	42.7	326.3	
53.9	129.0	43.1	326.9	
54.0	129.2	43.2	327.0	53.5°–54.5° C. Japanese wax melts
54.4	130.0	43.6	327.4	
55.0	131.0	44.0	328.0	55° C. methyl alcohol boils
55.6	132.0	44.4	328.6	
56.0	132.8	44.8	329.0	
56.1	133.0	44.9	329.1	
56.7	134.0	45.3	329.7	
57.0	134.6	45.6	330.0	
57.2	135.0	45.8	330.2	
57.8	136.0	46.2	330.8	
58.0	136.4	46.4	331.0	
58.3	137.0	46.7	331.3	
58.9	138.0	47.1	331.9	
59.0	138.2	47.2	332.0	
59.4	139.0	47.6	332.4	
60.0	140.0	48.0	333.0	
60.6	141.0	48.4	333.6	60.5° C. Wood's alloy (Bi ₄ CdPb ₂ Sn) melts
61.0	141.8	48.8	334.0	
61.1	142.0	48.9	334.1	
61.7	143.0	49.3	334.7	
62.0	143.6	49.6	335.0	62° C. chloroform boils
62.2	144.0	49.8	335.2	62°–62.5° C. yellow bees' wax melts
62.8	145.0	50.2	335.8	62.1° C. potassium melts
63.0	145.4	50.4	336.0	63° C. bromine boils
63.3	146.0	50.7	336.3	63°–63.5° C. white bees' wax melts
63.9	147.0	51.1	336.9	
64.0	147.2	51.2	337.0	
64.4	148.0	51.6	337.4	
65.0	149.0	52.0	338.0	
65.6	150.0	52.4	338.6	65.5° C. alloy Cd ₄ Sn ₅ Pb ₅ Bi ₁₀ melts
66.0	150.8	52.8	339.0	
66.1	151.0	52.9	339.1	
66.7	152.0	53.3	339.7	

THERMOMETER SCALES—(Continued).

Centi- grade Deg.	Fahren- heit Deg.	Réau- mur Deg.	Abso- lute Deg.	Concrete Scale (mostly only approximate).
67.0	152.6	53.6	340.0	67.5° C. alloy $\text{Cd}_3\text{Sn}_4\text{Pb}_4\text{Bi}_8$ melts
67.2	153.0	53.8	340.2	
67.8	154.0	54.2	340.8	
68.0	154.4	54.4	341.0	
68.3	155.0	54.7	341.3	
68.9	156.0	55.1	341.9	68.5° C. alloy CdSnPbBi_2 melts
69.0	156.2	55.2	342.0	
69.4	157.0	55.6	342.4	70° C. hexane boils
70.0	158.0	56.0	343.0	
70.6	159.0	56.4	343.6	
71.0	159.8	56.8	344.0	
71.1	160.0	56.9	344.1	
71.7	161.0	57.3	344.7	
72.0	161.6	57.6	345.0	
72.2	162.0	57.8	345.2	
72.8	163.0	58.2	345.8	
73.0	163.4	58.4	346.0	
73.3	164.0	58.7	346.3	
73.9	165.0	59.1	346.9	
74.0	165.2	59.2	347.0	
74.4	166.0	59.6	347.4	
75.0	167.0	60.0	348.0	
75.6	168.0	60.4	348.6	
76.0	168.8	60.8	349.0	
76.1	169.0	60.9	349.1	
76.7	170.0	61.3	349.7	
77.0	170.6	61.6	350.0	
77.2	171.0	61.8	350.2	78.4° C. pure ethyl alcohol boils
77.8	172.0	62.2	350.8	
78.0	172.4	62.4	351.0	
78.3	173.0	62.7	351.3	
78.9	174.0	63.1	351.9	
79.0	174.2	63.2	352.0	79.2° C. naphthalene melts
79.4	175.0	63.6	352.4	
80.0	176.0	64.0	353.0	
80.6	177.0	64.4	353.6	80.4° C. benzene, at 760 mm pressure, boils
81.0	177.8	64.8	354.0	
81.1	178.0	64.9	354.1	
81.7	179.0	65.3	354.7	
82.0	179.6	65.6	355.0	
82.2	180.0	65.8	355.2	
82.8	181.0	66.2	355.8	
83.0	181.4	66.4	356.0	
83.3	182.0	66.7	356.3	
83.9	183.0	67.1	356.9	
84.0	183.2	67.2	357.0	
84.4	184.0	67.6	357.4	
85.0	185.0	68.0	358.0	
85.6	186.0	68.4	358.6	
86.0	186.8	68.8	359.0	

THERMOMETER SCALES (*Continued*).

Centi- grade Deg.	Fahren- heit Deg.	Réau- mur Deg.	Abso- lute Deg.	Concrete Scale (mostly only approximate).
86.1	187.0	68.9	359.1	
86.7	188.0	69.3	359.7	
87.0	188.6	69.6	360.0	
87.2	189.0	69.8	360.2	
87.8	190.0	70.2	360.8	
88.0	190.4	70.4	361.0	
88.3	191.0	70.7	361.3	
88.9	192.0	71.1	361.9	
89.0	192.2	71.2	362.0	
89.4	193.0	71.6	362.4	89.5° C. alloy CdPb ₃ Bi ₄ melts
90.0	194.0	72.0	363.0	
90.6	195.0	72.4	363.6	
91.0	195.8	72.8	364.0	
91.1	196.0	72.9	364.1	
91.7	197.0	73.3	364.7	
92.0	197.6	73.6	365.0	92° C. potash alum melts
92.2	198.0	73.8	365.2	
92.8	199.0	74.2	365.8	
93.0	199.4	74.4	366.0	
93.3	200.0	74.7	366.3	
93.9	201.0	75.1	366.9	93.7° C. Rose's alloy, Bi ₂ PbSn, melts
94.0	201.2	75.2	367.0	
94.4	202.0	75.6	367.4	
95.0	203.0	76.0	368.0	95° C. alloy Cd ₂ Pb ₇ Bi ₈ melts
95.6	204.0	76.4	368.6	95.6° C. sodium melts
96.0	204.8	76.8	369.0	
96.1	205.0	76.9	369.1	
96.7	206.0	77.3	369.7	
97.0	206.6	77.6	370.0	
97.2	207.0	77.8	370.2	
97.8	208.0	78.2	370.8	
98.0	208.4	78.4	371.0	
98.3	209.0	78.7	371.3	
98.9	210.0	79.1	371.9	
99.0	210.2	79.2	372.0	
99.4	211.0	79.6	372.4	
100.0	212.0	80.0	373.0	100° C. water boils
100.6	213.0	80.4	373.6	
101.0	213.8	80.8	374.0	
101.1	214.0	80.9	374.1	
101.7	215.0	81.3	374.7	
102.0	215.6	81.6	375.0	
102.2	216.0	81.8	375.2	
102.8	217.0	82.2	375.8	
103.0	217.4	82.4	376.0	
103.3	218.0	82.7	376.3	
103.9	219.0	83.1	376.9	
104.0	219.2	83.2	377.0	
104.4	220.0	83.6	377.4	104.4° C. vitreous selenium melts
105.0	221.0	84.0	378.0	

THERMOMETER SCALES—(Continued).

Centi- grade Deg.	Fahren- heit Deg.	Absol- ute Deg.	Concrete Scale (mostly only approximate).
105.6	222.0	378.6	
106.0	222.8	379.0	
106.1	223.0	379.1	
106.7	224.0	379.7	
107.0	224.6	380.0	
107.2	225.0	380.2	
107.8	226.0	380.8	
108.0	226.4	381.0	
108.3	227.0	381.3	
108.9	228.0	381.9	
109.0	228.2	382.0	
109.4	229.0	382.4	
110.0	230.0	383.0	
110.6	231.0	383.6	
111.0	231.8	384.0	
111.1	232.0	384.1	
111.7	233.0	384.7	
112.0	233.6	385.0	
112.2	234.0	385.2	
112.8	235.0	385.8	110°–115° C. ferric sulphate melts
113.0	235.4	386.0	
113.3	236.0	386.3	
113.9	237.0	386.9	
114.0	237.2	387.0	
114.4	238.0	387.4	114.5° C. rhombic sulphur and copper nitrate, [(Cu(NO ₃) ₂ ·3H ₂ O), melt
115.0	239.0	388.0	115° C. iodine melts
115.6	240.0	388.6	
116.0	240.8	389.0	
116.1	241.0	389.1	
116.7	242.0	389.7	
117.0	242.6	390.0	
117.2	243.0	390.2	
117.8	244.0	390.8	
118.0	244.4	391.0	
118.3	245.0	391.3	
118.9	246.0	391.9	
119.0	246.2	392.0	
119.4	247.0	392.4	
120.0	248.0	393.0	120° C. prismatic sulphur melts
120.6	249.0	393.6	
121.0	249.8	394.0	
121.1	250.0	394.1	
121.7	251.0	394.7	
122.0	251.6	395.0	
122.2	252.0	395.2	
122.8	253.0	395.8	
123.0	253.4	396.0	
123.3	254.0	396.3	
123.9	255.0	396.9	
124.0	255.2	397.0	

THERMOMETER SCALES—(Continued).

Centi- grade Deg.	Fahren- heit Deg.	Abso- lute Deg.	Concrete Scale (mostly only approximate)
124.4	256.0	397.4	125.3° C. alloy Pb_3Bi_8 melts
125.0	257.0	398.0	
125.6	258.0	398.6	
126.0	258.8	399.0	
126.1	259.0	399.1	
126.7	260.0	399.7	131° C. amyl alcohol boils
127.0	260.6	400.0	
127.2	261.0	400.2	
127.8	262.0	400.8	
128.0	262.4	401.0	
128.3	263.0	401.3	
128.9	264.0	401.9	
129.0	264.2	402.0	
129.4	265.0	402.4	
130.0	266.0	403.0	
130.6	267.0	403.6	134° C. $\text{Al}(\text{NO}_3)_3 + 9\text{H}_2\text{O}$ boils
131.0	267.8	404.0	
131.1	268.0	404.1	
131.7	269.0	404.7	
132.0	269.6	405.0	
132.2	270.0	405.2	136.4° C. alloy Sn_3Bi_4 melts
132.8	271.0	405.8	
133.0	271.4	406.0	
133.3	272.0	406.3	
133.9	273.0	406.9	
134.0	273.2	407.0	138.12° C. sulphur monochloride, at 760 mm pres- [sure, boils
134.4	274.0	407.4	
135.0	275.0	408.0	
135.6	276.0	408.6	
136.0	276.8	409.0	
136.1	277.0	409.1	140° C. ferrous sulphate + 6 aq. melts
136.7	278.0	409.7	
137.0	278.6	410.0	
137.2	279.0	410.2	
137.8	280.0	410.8	
138.0	280.4	411.0	142° C. ferrous sulphate + 6 aq. melts
138.3	281.0	411.3	
138.9	282.0	411.9	
139.0	282.2	412.0	
139.4	283.0	412.4	
140.0	284.0	413.0	143° C. ferrous sulphate + 6 aq. melts
140.6	285.0	413.6	
141.0	285.8	414.0	
141.1	286.0	414.1	
141.7	287.0	414.7	
142.0	287.6	415.0	146° C. ferrous sulphate + 6 aq. melts
142.2	288.0	415.2	
142.8	289.0	415.8	
143.0	289.4	416.0	
143.3	290.0	416.3	

THERMOMETER SCALES—(Continued).

Centi- grade Deg.	Fahren- heit Deg.	Abso- lute Deg.	Concrete Scale (mostly only approximate).
143.9	291.0	416.9	
144.0	291.2	417.0	
144.4	292.0	417.4	
145.0	293.0	418.0	
145.6	294.0	418.6	
146.0	294.8	419.0	146° C. SnI_4 melts
146.1	295.0	419.1	146.3° C. alloy CdBi_4 melts
146.7	296.0	419.7	
147.0	296.6	420.0	
147.2	297.0	420.2	
147.8	298.0	420.8	
148.0	298.4	421.0	
148.3	299.0	421.3	
148.9	300.0	421.9	
149.0	300.2	422.0	
149.4	301.0	422.4	
150.0	302.0	423.0	
152.0	305.6	425.0	
154.0	309.2	427.0	
156.0	312.8	429.0	
158.0	316.4	431.0	
160.0	320.0	433.0	160° C. pure sugar melts
162.0	323.6	435.0	161° C. turpentine boils
164.0	327.2	437.0	
166.0	330.8	439.0	
168.0	344.4	441.0	
170.0	338.0	443.0	170° C. copper nitrate, $(\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O})$, boils
172.0	341.6	445.0	
174.0	345.2	447.0	173.8° C. alloy CdSn_2 melts
176.0	348.8	449.0	175° C. ordinary camphor, $(\text{C}_{10}\text{H}_{16}\text{O})$, melts
178.0	352.4	451.0	178° C. caffeine melts
180.0	356.0	453.0	180° C. aluminium chloride boils
182.0	359.6	455.0	180° C. lithium melts
184.0	363.2	457.0	181° C. aniline boils
186.0	366.8	459.0	181° C. alloy PbSn_3 melts
188.0	370.4	461.0	182° C. phenol (carbolic acid) boils
190.0	374.0	463.0	187° C. alloy PbSn_4 melts
192.0	377.6	465.0	
194.0	381.2	467.0	
196.0	384.8	469.0	
198.0	388.4	471.0	197° C. alloy PbSn_2 melts
200.0	392.0	473.0	204° C. ordinary camphor, $(\text{C}_{10}\text{H}_{16}\text{O})$, boils
205.0	401.0	478.0	216.4°–216.8° C. naphthalene boils
210.0	410.0	483.0	217° C. crystalline selenium insol. in CS_2 melts
215.0	419.0	488.0	218° C. silver nitrate melts
220.0	428.0	493.0	221° C. very faint yellow in tempering steel
225.0	437.0	498.0	230° C. silver chlorate melts
230.0	446.0	503.0	232° C. pale straw yellow in tempering steel
235.0	455.0	508.0	235° C. tin melts
240.0	464.0	513.0	235° C. alloy PbSn melts

THERMOMETER SCALES—(Continued).

Centi- grade Deg.	Fahren- heit Deg.	Absol- ute Deg.	Concrete Scale (mostly only approximate).
245.0	473.0	518.0	243° C. full yellow color in tempering steel
250.0	482.0	523.0	251° C. silver chloride melts
254.0	489.2	527.0	254° C. brown color in tempering steel
255.0	491.0	528.0	255° C. red phosphorus melts
260.0	500.0	533.0	262° C. zinc chloride melts
265.0	509.0	538.0	266° C. red color in tempering steel
270.0	518.0	543.0	269° C. bismuth melts
275.0	527.0	548.0	270° C. alloy Pb_2Sn melts
280.0	536.0	553.0	277° C. purple color in tempering steel
283.0	541.4	556.0	283° C. alloy Pb_3Sn melts
285.0	545.0	558.0	275°–280° C. glycerine distills
288.0	550.4	561.0	287.3° C. yellow phosphorus boils at 762 mm
290.0	554.0	563.0	288° C. mercuric chloride melts
295.0	563.0	568.0	288° C. bright-blue color in tempering steel
300.0	572.0	573.0	292° C. alloy Pb_4Sn melts
305.0	581.0	578.0	293° C. full blue color in tempering steel
310.0	590.0	583.0	302° C. sodium chlorate melts
315.0	599.0	588.0	303° C. mercuric chloride boils
320.0	608.0	593.0	316° C. sodium nitrate melts
325.0	617.0	598.0	316° C. dark-blue color in tempering steel
330.0	626.0	603.0	320°–327° C. cadmium melts
335.0	635.0	608.0	327° C. lead melts
340.0	644.0	613.0	338° C. pure sulphuric acid, sp. gr. 1.854, boils
345.0	653.0	618.0	339° C. potassium nitrate melts
350.0	662.0	623.0	357.25° C. mercury boils
360.0	680.0	633.0	359° C. potassium chlorate melts
370.0	698.0	643.0	
380.0	716.0	653.0	
390.0	734.0	663.0	
400.0	752.0	673.0	
410.0	770.0	683.0	414° C. barium chlorate melts
420.0	788.0	693.0	419° C. zinc melts (Berthelot)
430.0	806.0	703.0	434° C. cuprous chloride melts
440.0	824.0	713.0	445° C. sulphur boils (Berthelot)
450.0	842.0	723.0	446° C. tellurium melts
460.0	860.0	733.0	448.4° C. sulphur at 760 mm boils (Carnelley)
470.0	878.0	743.0	
480.0	896.0	753.0	482° C. sodium perchlorate melts
490.0	914.0	763.0	486° C. silver perchlorate melts
500.0	932.0	773.0	498° C. lead chloride and cupric chloride melt
510.0	950.0	783.0	505° C. barium perchlorate melts
520.0	968.0	793.0	525° C. first visible red of incandescent bodies [(Pouillet)]
530.0	986.0	803.0	
540.0	1 004.0	813.0	541° C. cadmium chloride melts
550.0	1 022.0	823.0	
560.0	1 040.0	833.0	561° C. calcium nitrate melts
570.0	1 058.0	843.0	561° C. borax melts
580.0	1 076.0	853.0	
590.0	1 094.0	863.0	
600.0	1 112.0	873.0	598° C. lithium chloride melts

THERMOMETER SCALES—(Continued).

Centi- grade Deg.	Fahr. Deg.	Absol- ute Deg.	Concrete Scale (mostly only approximate).
610	1 130	883	610° C. potassium perchlorate melts
620	1 148	893	617°–628° C. stannous chloride boils
630	1 166	903	632° C. antimony melts
640	1 184	913	
650	1 202	923	650° C. NaCl and KCl in molecular proportions melt
660	1 220	933	657° C. aluminium melts
670	1 238	943	664°–666° C. crystalline selenium boils at 760 mm
680	1 256	953	676°–683° C. zinc chloride boils
690	1 274	963	
700	1 292	973	700° C. (about) dull-red incandescence (Pouillet)
710	1 310	983	708° C. magnesium chloride melts
720	1 328	993	719° C. calcium chloride, (CaCl ₂), melts (see also [28.5° C.]
730	1 346	1 003	719°–731° C. potassium boils
740	1 364	1 013	734° C. potassium chloride melts
750	1 382	1 023	750° C. magnesium melts
760	1 400	1 033	763°–772° C. cadmium boils
770	1 418	1 043	772° C. sodium chloride (kitchen salt) melts
780	1 436	1 053	
790	1 454	1 063	
800	1 472	1 073	800° C. incipient cherry-red (Pouillet)
810	1 490	1 083	814° C. sodium carbonate melts
820	1 508	1 093	818° C. lithium sulphate melts
830	1 526	1 103	834° C. potassium carbonate melts
840	1 544	1 113	847° C. alloy 63% silver + 37% copper melts
850	1 562	1 123	850° C. alloy 75% silver + 25% copper melts
860	1 580	1 133	861° C. sodium sulphate melts
870	1 598	1 143	870.5° C. alloy 71.9% silver + 28.1% copper melts
880	1 616	1 153	886° C. “ 82.1% “ + 17.9% “ “
890	1 634	1 163	900° C. “ 57% “ + 43% “ “
900	1 652	1 173	900° C. cherry-red incandescence (Pouillet)
920	1 688	1 193	902° C. calcium fluoride melts
940	1 724	1 213	950° C. zinc boils
960	1 760	1 233	968° C. silver melts
980	1 796	1 253	975° C. alloy 60% silver + 40% gold melts
1 000	1 832	1 273	1 000° C. bright cherry-red (Pouillet)
1 020	1 868	1 293	1 015° C. potassium sulphate melts
1 040	1 904	1 313	1 050°–1 100° C. white pig iron melts
1 060	1 940	1 333	1 064° C. gold melts (Berthelot)
1 080	1 976	1 353	1 084° C. copper melts
1 100	2 012	1 373	1 100° C. dull-orange incandescence (Pouillet)
1 120	2 048	1 393	1 100° C. alloy 95% gold + 5% platinum melts
1 140	2 084	1 413	1 130° C. “ 90% “ + 10% “ “
1 160	2 120	1 433	1 150° C. limit of gas thermometers, bulb softens
1 180	2 156	1 453	1 190° C. alloy 80% gold + 20% platinum melts
1 200	2 192	1 473	1 200° C. bright-orange incandescence (Pouillet)
1 220	2 228	1 493	1 200° C. (about) gray pig iron melts
1 240	2 264	1 513	1 245° C. manganese 99% pure melts (Heraeus)
1 260	2 300	1 533	1 255° C. alloy 70% gold + 30% platinum melts
1 280	2 336	1 553	1 285° C. “ 65% “ + 35% “ “
1 300	2 372	1 573	1 300° C. white incandescence (Pouillet)

THERMOMETER SCALES—(*Concluded*).

Centi- grade Deg.	Fahr. Deg.	Abso- lute Deg.	Concrete Scale (mostly only approximate).
1 320	2 408	1 593	1 320° C. alloy 60% gold + 40% platinum melts
1 340	2 444	1 613	1 350° C. " 55% " + 45% " "
1 360	2 480	1 633	1 350° C. Bunsen flame; inner blue flame (Kelvin)
1 380	2 516	1 653	1 370° C. furnace temperature for hard porcelain
1 400	2 552	1 673	1 375° C. glass furnace temperature
1 420	2 588	1 693	1 400° C. bright-white incandescence (Pouillet)
1 440	2 624	1 713	1 400° C. Bessemer steel melts
1 460	2 660	1 733	1 460° C. alloy 40% gold + 60% platinum melts
1 480	2 696	1 753	1 490° C. Siemens-Martin steel melts
1 500	2 732	1 773	1 500° C. dazzling-white heat (Pouillet)
1 520	2 768	1 793	1 500° C. palladium melts; tin boils
1 540	2 804	1 813	1 535° C. alloy 30% gold + 70% platinum melts
1 560	2 840	1 833	1 425°–1 625° C. temp. Argand gas-burner (Lummer)
1 580	2 876	1 853	1 490°–1 580° C. temp. in Siemens-Martin furnace
1 600	2 912	1 873	1 475°–1 685° C. temp. candle-flame (Lummer)
1 620	2 948	1 893	1 610° C. alloy 20% gold + 80% platinum melts
1 640	2 984	1 913	1 650° C. " 15% " + 85% " "
1 660	3 020	1 933	1 600°–1 825° C. temp. inc. elec. lamp (Lummer)
1 680	3 056	1 953	1 690° C. alloy 10% gold + 90% platinum melts
1 700	3 092	1 973	1 700° C. bismuth boils
1 720	3 128	1 993	1 730° C. alloy 5% gold + 95% platinum melts
1 740	3 164	2 013	1 600°–1 800° C. thallium boils
1 760	3 200	2 033	
1 780	3 236	2 053	1 779° C. platinum melts
1 800	3 272	2 073	1 800° C. cobalt melts
1 825	3 317	2 098	1 820° C. Bunsen flame blast-lamp (Kelvin)
1 850	3 362	2 123	
1 875	3 407	2 148	1 800°–2 000° C. pure wrought iron melts
1 900	3 452	2 173	1 900° C. manganese melts
1 925	3 497	2 198	
1 950	3 542	2 223	1 950° C. iridium melts
1 975	3 587	2 248	
2 000	3 632	2 273	1 800°–2 000° C. pure wrought iron melts
2 100	3 812	2 373	2 000° C. rhodium melts
2 500	4 532	2 773	1 925°–2 175° C. temp. of Nernst lamp and Welsbach [mantel (Lummer)]
3 000	5 432	3 273	2 500° C. osmium melts
3 500	6 332	3 773	2 844° C. oxyhydrogen flame (Bunsen)
4 000	7 232	4 273	3 475°–3 927° C. temp. electric (carbon) arc light [(Lummer)]
5 000	9 032	5 273	
6 000	10 832	6 273	5 000° C. temperature of the sun (Lummer)

Exceedingly high temperatures of the order of millions of degrees have been calculated to be produced, on certain theoretical assumptions, by the impact of some kinds of rays, like the X-rays; but owing to the exceedingly small quantity of the heat and the enormously rapid conduction they cannot be maintained.

Note.—Any inconsistencies that may appear in some of the high-temperature values in the last column are no doubt due in part to the different methods by which they were determined; the values are generally only approximations.

MONEY.

The values of foreign moneys in the terms of the U. S. gold dollar, as given below, are those used by the United States Treasury Department in 1903 for estimating the value of all foreign merchandise exported to the United States expressed in the metallic currencies of those countries. (See *Department Circular* No. 37 of 1903 of the Treasury Department.) The values refer to the standard specie money of those countries and were determined by the U. S. Mint in terms of the U. S. gold dollar; they are therefore the true relative values, gold being the basis of comparison. The reciprocal values were calculated from these. The coins of silver-standard countries are valued by their pure silver contents at the average market price of silver during the beginning of the year 1903. Much of the money in foreign countries is paper money, the value of which is subject to many fluctuations, and is generally not received at its par value.

Unless otherwise stated the standard of the countries in the following list is gold. France, Belgium, Italy, Switzerland, and Greece form the Latin Union; their standard coins have the same value.

Argentine Republic. 1 peso = 0.965 U. S. gold dollar = 100 centavos. 1 argentine (gold) = 5 pesos = 4.824 U. S. gold dollars. 1 U. S. gold dollar = 1.036 pesos.

Austria-Hungary. 1 crown (Krone) = 0.203 U. S. gold dollar. 1 U. S. gold dollar = 4.923 crowns. The small unit is the heller. The former units were 1 florin = 0.482 U. S. gold dollar = 100 kreutzer. (The usual exchange value is much lower, being about 41 cts., and fluctuates considerably.) Money orders issued in the United States are drawn on French money (francs); 1 crown = about 1.05 francs.

Belgium. 1 franc = 0.193 U. S. gold dollar = 100 centimes. 1 U. S. gold dollar = 5.18 francs.

Bolivia (silver standard). 1 boliviano = 0.352 U. S. gold dollar = 100 centavos. 1 U. S. gold dollar = 2.84 bolivianos.

Brazil. 1 milreis = 0.546 U. S. gold dollar = 1 000 reis. 1 U. S. gold dollar = 1.83 milreis.

British Honduras. 1 dollar = 1 U. S. gold dollar = 100 cents.

British Possessions in North America (except Newfoundland). 1 dollar = 1 U. S. gold dollar.

Canada. See British Possessions.

Central American States. See individual States.

Ceylon. Rupee. See India.

Chile. 1 peso = 0.365 U. S. gold dollar = 10 dineros or decimos = 100 centavos. 1 U. S. gold dollar = 2.740 pesos. 1 condor (gold) = 7.300 U. S. gold dollars = 2 doubloons = 4 escudos = 20 pesos.

China (silver standard). 1 tael (average value) = 0.549 U. S. gold dollar. 1 U. S. gold dollar = 1.82 taels (average value). The tael has different values in different cities, varying from 0.520 to 0.580 dollar. The "British dollar" has the same legal value as the Mexican dollar in Hong-kong, the Straits Settlements, and Labuan.

Colombia (silver standard). 1 peso = 0.352 U. S. gold dollar = 10 diernos or decimos = 100 centavos. 1 U. S. gold dollar = 2.84 pesos. 1 condor (gold) = 9.647 U. S. gold dollars.

Costa Rica. 1 colon = 0.465 U. S. gold dollar = 100 centimos. 1 U. S. gold dollar = 2.15 colons.

Cuba. 1 peso = 0.926 U. S. gold dollar. 1 U. S. gold dollar = 1.080 pesos. 1 doubloon Isabella, centen = 5.017 U. S. gold dollars. 1 Alphonse = 4.823 U. S. gold dollars.

Denmark. 1 crown (Krone) = 0.268 U. S. gold dollar = 100 oere. 1 U. S. gold dollar = 3.73 crowns.

Ecuador. 1 sucre = 0.487 U. S. gold dollar. 1 U. S. gold dollar = 2 05 sucres.

Egypt. 1 pound = 4.943 U. S. gold dollars = 100 piasters = 4 000 paras. 1 U. S. gold dollar = 0.202 pound.

Finland. 1 mark (markka) = 0.193 U. S. gold dollar = 100 penni. 1 U. S. gold dollar = 5.18 marks.

France. 1 franc=0.193 U. S. gold dollar=100 centimes. 1 Louis or Napoleon=20 francs 1 sou=5 centimes=about 1 cent (U. S.). 1 U. S. gold dollar=5.18 francs. 1 U. S. cent=5 18 centimes=about 1 sou 20 francs=3.86 U. S. gold dollars. 1 franc=0.811 mark (German)=0.793 shilling (English).

German Empire. 1 mark=0.238 U. S. gold dollar=100 pfennig 1 U. S. gold dollar=4.20 marks. 1 pfennig=0.238 cent; 1 cent=4.20 pfennigs. 1 mark=1.233 francs (French)=0.978 shilling or 11 72 pence (English).

Great Britain. 1 pound sterling [£] or sovereign=4.8665 U. S. gold dollars=20 shillings=240 pence=960 farthings. 1 U. S. dollar=0.205 49 pound sterling. 1 guinea=21 shillings=5.11 U. S. gold dollars. 1 half crown=2 5 shillings=.608 3 U. S. gold dollar. 1 shilling [s]=24.33 cents=0.05 £=12 pence=48 farthings=1.022 marks (German)=1.261 francs (French). 1 U. S. gold dollar=4.109 8 shillings. 1 penny (plural pence) [d]=2.03 cents=0.0833 shilling=0.004167 £=10.51 centimes (French)=8.52 pfennig (German). 1 cent=0.493 penny.

Greece. 1 drachma=0.193 U. S. gold dollar=100 lepta. 1 U. S. gold dollar=5.18 drachmas.

Guatemala (silver standard). 1 peso=0.352 U. S. gold dollar. 1 U. S. gold dollar=2.84 pesos.

Haiti. 1 gourde=0.965 U. S. gold dollar=100 cents (Haiti). 1 U. S. gold dollar=1.036 gourdes.

Hawaii. See United States.

Honduras (silver standard). 1 peso=0.352 U. S. gold dollar. 1 U. S. gold dollar=2.84 pesos.

Honduras (British). 1 dollar=1 U. S. gold dollar=100 cents.

India. 1 pound sterling [£]=4.866 5 U. S. gold dollars (same standard as in Great Britain)=15 rupees (money of account). 1 rupee=0.324 4 U. S. gold dollar=16 annas. 1 U. S. gold dollar=0.205 49 pound sterling=3.082 rupees.

Italy. 1 lira=0.193 U. S. gold dollar=100 centesimi. 1 U. S. gold dollar=5.18 lire.

Japan. 1 yen=0.498 U. S. gold dollar=100 sen. 1 U. S. gold dollar=2.008 yen.

Liberia. Same as in the United States.

Mexico (silver standard). 1 dollar (silver), peso, or piastre=0.383 U. S. gold dollar=100 centavos. 1 dollar (gold)=0.983 U. S. gold dollar. 1 U. S. gold dollar=2.611 dollars (silver)=1.017 dollars (gold). 1 once or doubloon=16 pesos.

Netherlands. 1 florin of 100 cents=0.402 U. S. gold dollar. 1 U. S. gold dollar=2.49 florins.

Newfoundland. 1 dollar=1.014 U. S. gold dollars. 1 U. S. gold dollar=0.986 dollar.

Nicaragua (silver standard). 1 peso=0.352 U. S. gold dollar. 1 U. S. gold dollar=2.84 pesos.

Norway. 1 crown=0.268 U. S. gold dollar=100 ore=30 skillings. 1 U. S. gold dollar=3.73 crowns.

Persia (silver standard). 1 kran (silver)=0.065 U. S. gold dollar. 1 tomans (gold)=1.704 5 U. S. gold dollars. 1 U. S. gold dollar=15.4 krans=0.586 7 tomans (gold).

Peru. 1 sol=0.487 U. S. gold dollar=10 dineros=100 centavos. 1 libra (gold)=4.866 5 U. S. gold dollars. 1 U. S. gold dollar=2.053 sols=0.205 49 libra (gold).

Portugal. 1 milreis=1.080 U. S. gold dollars=10 testoons=1 000 reis. 1 crown=10 milreis. 1 U. S. gold dollar=0.925 9 milreis.

Russia. 1 ruble=0.515 U. S. gold dollar=2 poltinniks=4 tchetvertaks=5 abassis=10 griviniks=20 pietaks=100 kopecks. 1 imperial (gold)=15 rubles=7.718 U. S. gold dollars. 1 U. S. gold dollar=1.942 rubles. 1 kopeck=0.515 cent (U. S.); 1 cent=1.942 kopecks.

Sandwich Islands. See United States.

Salvador (silver standard). 1 peso=0.352 U. S. gold dollar. 1 U. S. gold dollar=2.84 pesos.

Sicily. See Italy.

Spain. 1 peseta or pistareen=0.193 U. S. gold dollar=100 centimes. 1 U. S. gold dollar=5.18 pesetas.

Sweden. 1 crown=0.268 U. S. gold dollar=100 oere. 1 U. S. gold dollar=3.73 crowns.

Switzerland. 1 franc = 0.193 U. S. gold dollar = 100 centimes. 1 U. S. gold dollar = 5.18 francs.

Turkey. 1 piaster = 0.044 U. S. gold dollar = 40 paras. 1 U. S. gold dollar = 22.73 piasters.

United States (and possessions). 1 dollar (\$) = 1 U. S. gold dollar = 10 dimes = 100 cents. 1 eagle = 20 dollars.

Uruguay. 1 peso = 1.034 U. S. gold dollars = 100 centavos or centesimos. 1 U. S. gold dollar = 0.967 peso.

Venezuela. 1 bolivar = 0.193 U. S. gold dollar = 2 decimos. 1 U. S. gold dollar = 5.18 bolivars. 1 venezolano = 5 bolivars.

FLUCTUATING CURRENCIES.

The November, 1903, issue, No. 278, vol. 73, of the *Monthly Consular Reports*, published by the Department of Commerce and Labor, gives a list of the fluctuating values of the silver units of several countries. The latest values, namely those for October 1, 1903, are as follows:

Bolivia, silver boliviano = \$0.408.

Central America, silver peso = \$0.408.

China, tael, average value = \$0.636.

Colombia, silver peso = \$0.408.

Mexico, silver dollar = \$0.443.

Persia, silver kran = \$0.075.

MONEY and LENGTH.

The money values used in this table are those given in the above list.

1 shilling per mile = 0.784 franc per kilometer.

= 0.635 mark per kilometer.

" = 0.243 3 dollar per mile.

1 franc per kilometer = 1.276 shillings per mile.

" = 0.811 mark per kilometer.

" = 0.311 dollar per mile.

1 mark per kilometer = 1.575 shillings per mile.

" = 1.233 francs per kilometer.

" = 0.383 dollar per mile.

1 dollar per mile = 4.11 shillings per mile.

" = 3.22 francs per kilometer.

" = 2.61 marks per kilometer.

1 cent per foot = 0.493 penny per foot.

" = 0.170 franc per meter.

" = 0.138 mark per meter.

1 penny per foot = 2.03 cents per foot.

" = 0.345 franc per meter.

" = 0.280 mark per meter.

1 franc per meter = 5.88 cents per foot.

" = 2.90 pence per foot.

" = 0.811 mark per meter.

1 mark per meter = 7.26 cents per foot.

" = 3.57 pence per foot.

" = 1.233 francs per meter.

MONEY and WEIGHT.

The money values used in this table are those given in the above list.

Av. means avoirdupois weights.

1 franc per metric ton	= 0.811 mark per metric ton.
"	= 0.806 shilling per long ton.
"	= 0.720 shilling per short ton.
"	= 0.196 dollar per long ton.
"	= 0.175 dollar per short ton.
1 mark per metric ton	= 1.233 francs per metric ton.
"	= 0.994 shilling per long ton.
"	= 0.888 shilling per short ton.
"	= 0.242 dollar per long ton.
"	= 0.216 dollar per short ton.
1 shilling per long ton	= 1.24 francs per metric ton.
"	= 1.005 marks per metric ton.
"	= 0.243 dollar per long ton.
"	= 0.217 dollar per short ton.
1 shilling per short ton	= 1.39 francs per metric ton.
"	= 1.13 marks per metric ton.
"	= 0.273 dollar per long ton.
"	= 0.243 dollar per short ton.
1 dollar per long ton	= 5.10 francs per metric ton.
"	= 4.14 marks per metric ton.
"	= 4.11 shillings per long ton.
"	= 3.67 shillings per short ton.
1 dollar per short ton	= 5.70 francs per metric ton.
"	= 4.63 marks per metric ton.
"	= 4.60 shillings per long ton.
"	= 4.11 shillings per short ton.
1 franc per kilogram	= 0.811 mark per kilogram.
"	= 0.547 cent per ounce (av.).
"	= 0.360 shilling per pound (av.).
"	= 0.270 penny per ounce (av.).
"	= 0.087 5 dollar per ounce (av.).
1 mark per kilogram	= 1.233 francs per kilogram.
"	= 0.675 cent per ounce (av.).
"	= 0.444 shilling per pound (av.).
"	= 0.333 penny per ounce (av.).
"	= 0.108 dollar per pound (av.).
1 cent per ounce [av.]	= 1.83 francs per kilogram.
"	= 1.48 marks per kilogram.
"	= 0.658 shilling per pound (av.).
"	= 0.493 penny per ounce (av.).
"	= 0.160 dollar per pound (av.).
1 shilling per pound [av.]	= 2.78 francs per kilogram.
"	= 2.25 marks per kilogram.
"	= 1.52 cents per ounce (av.).
"	= 0.750 penny per ounce (av.).
"	= 0.243 dollar per pound (av.).
1 penny per ounce [av.]	= 3.71 francs per kilogram.
"	= 3.00 marks per kilogram.
"	= 2.03 cents per ounce (av.).
"	= 1.333 shillings per pound (av.).
"	= 0.324 dollar per pound (av.).
1 dollar per pound [av.]	= 11.4 francs per kilogram.
"	= 9.26 marks per kilogram.
"	= 6.25 cents per ounce (av.).
"	= 4.11 shillings per pound (av.).
"	= 3.08 pence per ounce (av.).

SCALES of MAPS and DRAWINGS.

The following table is limited to the more usual values. For a very complete table of scales for maps, as distinguished from detail drawings, see Haupt, Scales of Maps, *Proceedings Engineers' Club of Philadelphia*, Vol. 1, p. 47-59, 1879. The relation of the meter to the foot which is there used is slightly different from the legal value in this country; the following are all based on the standard legal value.

When the scale of a map is given as $\frac{1}{n}$, then:

			Logarithm
1 inch on the map	$=n \times$	2.540 005 centimeters.....	0.404 8346
"	$=n \times$	1. inches.....	0.000 0000
"	$=n \times$	0.083 333 3 feet.....	2.920 8188
"	$=n \times$	0.027 777 8 yards.....	2.443 6975
"	$=n \times$	0.025 400 05 meters.....	2.404 8346
"	$=n \times$	0.005 050 51 rods.....	3.703 3348
"	$=n \times$	0.001 262 63 chains.....	3.101 2749
"	$=n \times$	0.000 025 400 05 kilometers.....	5.404 8346
"	$=n \times$	0.000 015 782 8 miles.....	5.198 1849
1 centimeter on the map	$=n \times$	1. centimeters	0.000 0000
"	$=n \times$	0.393 700 inches.....	1.595 1654
"	$=n \times$	0.032 808 3 feet.....	2.515 9842
"	$=n \times$	0.010 936 1 yards.....	2.038 8629
"	$=n \times$	0.01 meters.....	2.000 0000
"	$=n \times$	0.001 988 38 rods.....	2.298 5002
"	$=n \times$	0.000 497 096 chains.....	4.696 4403
"	$=n \times$	0.000 01 kilometers..	5.000 0000
"	$=n \times$	0.000 006 213 70 miles.....	6.793 3503

Special values of the above, frequently used. The first length refers to the actual distance and the second to the map or drawing.

Scale of	1/12	=	1 foot to the inch.
"	1/120	=	10 feet to the inch.
"	1/198	=	1 rod to the inch.
"	1/240	=	20 feet to the inch.
"	1/360	=	30 feet to the inch.
"	1/480	=	40 feet to the inch.
"	1/600	=	50 feet to the inch.
"	1/720	=	60 feet to the inch.
"	1/960	=	80 feet to the inch.
"	1/120 0	=	100 feet to the inch.
"	1/63 360	=	1 mile to the inch.
"	1/100 000	=	1 kilometer to the centimeter.

Scales for Detail Drawings. The first length refers to the drawing and the second to the actual length.

Full size	=	12	inches to the foot.
Half size	=	6	" " " "
Third size	=	4	" " " "
Quarter size	=	3	" " " "
Sixth size	=	2	" " " "
Eighth size	=	1½	" " " "
Twelfth size	=	1	inch " " " "
Sixteenth size	=	¾	" " " "
Twenty-fourth size	=	½	" " " "
Thirty-second size	=	⅜	" " " "
Forty-eighth size	=	¼	" " " "
Ninety-sixth size	=	⅙	" " " "

PAPER MEASURE. MISCELLANEOUS MEASURES.

1 quire = 24 or 25 sheets.	1 dozen = 12.
1 ream = 20 quires = 480 sheets.	1 gross = 12 dozen = 144.
1 ream = generally 500 sheets.	1 great gross = 12 gross.
1 bundle (obs.) = 2 reams = 1 000 sheets.	1 great gross = 144 dozen = 1728.
1 bale (obsolete) = 5 bundles.	1 score = 20.

USEFUL FUNCTIONS OF π .

Logarithm

Aprx. means within 2%.

 π (called "pi") = circumference of a circle divided by the diameter and is a constant. π = approximately $22\frac{7}{11}$, which equals 3.142 86 or $\frac{4}{100}\%$ too much. π = approximately $355\frac{1}{113}$, which equals 3.141 592 9.

π =	3.141 592 653 589 793 238 462 643 383 279 502 88.† ...	0.497 1499
2π =	6.283 185 307 180.....	0.798 1799
3π =	9.424 777 960 769.....	0.974 2711
4π =	12.566 370 614 359. Aprx. $\frac{1}{8} \times 100$	1.099 2099
5π =	15.707 963 267 949.....	1.196 1199
6π =	18.849 555 921 539.....	1.275 3011
7π =	21.991 148 575 129.....	1.342 2479
8π =	25.132 741 228 718.....	1.400 2398
9π =	28.274 333 882 308.....	1.451 3924
10π =	31.415 926 535 898.....	1.497 1499
$4\pi/3$ =	4.188 790 204 786.....	0.622 0886

$\pi/1$ =	3.141 592 7. Aprx. $22\frac{7}{11}$	0.497 1499
$\pi/2$ =	1.570 796 3. Aprx. $11\frac{7}{11}$	0.196 1199
$\pi/3$ =	1.047 197 6.....	0.020 0286
$\pi/4$ =	0.785 398 2. Aprx. $\frac{8}{10}$	1.895 0899
$\pi/5$ =	0.628 318 5.....	1.798 1799
$\pi/6$ =	0.523 598 8.....	1.718 9986
$\pi/7$ =	0.448 799 0.....	1.652 0518
$\pi/8$ =	0.392 699 1.....	1.594 0599
$\pi/9$ =	0.349 065 9.....	1.542 9074
$\pi/10$ =	0.314 159 3.....	1.497 1499
$\pi/12$ =	0.261 799 4.....	1.417 9686
$\pi/16$ =	0.196 349 5.....	1.293 0298
$\pi/32$ =	0.098 174 8.....	2.991 9999
$\pi/64$ =	0.049 087 4.....	2.690 9698
$\pi/108$ =	0.029 088 8.....	2.463 7261
$\pi/180$ =	0.017 453 3.....	2.241 8774
$\pi/360$ =	0.008 726 65.....	3.940 8474

$1 \times \pi/4$ =	0.785 398 2. Aprx. $\frac{8}{10}$	1.895 0899
$2 \times \pi/4$ =	1.570 796 3.....	0.196 1199
$3 \times \pi/4$ =	2.356 194 5.....	0.372 2112
$4 \times \pi/4$ =	3.141 592 7.....	0.497 1499
$5 \times \pi/4$ =	3.926 990 8.....	0.594 0599
$6 \times \pi/4$ =	4.712 389 0.....	0.673 2411
$7 \times \pi/4$ =	5.497 787 1.....	0.740 1879
$8 \times \pi/4$ =	6.283 185 3.....	0.798 1799
$9 \times \pi/4$ =	7.068 583 5.....	0.849 3324
$10 \times \pi/4$ =	7.853 981 6.....	0.895 0899

$1/\pi$ =	0.318 309 9. Aprx. $\frac{7}{22}$	1.502 8501
$2/\pi$ =	0.636 619 8.....	1.803 8801
$3/\pi$ =	0.954 929 7.....	1.979 9713
$4/\pi$ =	1.273 239 5.....	0.104 9101
$5/\pi$ =	1.591 549 4.....	0.201 8201
$6/\pi$ =	1.909 859 3.....	0.281 0014
$7/\pi$ =	2.228 169 2.....	0.347 9482
$8/\pi$ =	2.546 479 1.....	0.405 9401
$9/\pi$ =	2.864 789 0.....	0.457 0926
$10/\pi$ =	3.183 098 9.....	0.502 8501
$12/\pi$ =	3.819 718 6.....	0.582 0314

† Ludolph's value. For Vega's value to 140 decimal places see *Histoire des Recherches sur la Quadrature du Cercle*, by Montucla, 1831, p. 282

	Logarithm
$\pi\sqrt{2} = 4.442\ 882\ 9\dots\dots\dots$	0.647 6649
$\pi \div \sqrt{2} = 2.221\ 441\ 4\dots\dots\dots$	0.346 6349
$4\pi \div 10 = 1.256\ 637\ 061\dots\dots\dots$ Aprx. add $\frac{1}{4}$	0.099 2099
$\pi^2 = 9.869\ 604\ 401\ 089\dots\dots\dots$ Aprx. 10	0.994 2997
$4\pi^2 = 39.478\ 418\dots\dots\dots$ Aprx. 40	1.596 3597
$\pi^2 \div 4 = 2.467\ 401\ 10\dots\dots\dots$ Aprx. $\frac{1}{4} \times 10$	0.392 2397
$\pi^3 = 31.006\ 276\ 680\ 300\dots\dots\dots$	1.491 4496
$\pi^4 = 97.409\ 091\dots\dots\dots$	1.988 5995
$\pi^5 = 306.019\ 69\dots\dots\dots$	2.485 7494
$\pi^6 = 961.389\ 19\dots\dots\dots$	2.982 8992
$1 + \pi^2 = 0.101\ 321\ 2\dots\dots\dots$	1.005 7003
$1 + \pi^3 = 0.032\ 251\ 5\dots\dots\dots$	2.508 5504
$\sqrt{\pi} = 1.772\ 453\ 850\ 908\dots\dots\dots$	0.248 5749
$2\sqrt{\pi} = 3.544\ 907\ 6\dots\dots\dots$	0.549 6049
$\sqrt{2\pi} = 2.506\ 628\dots\dots\dots$	0.399 0899
$\sqrt[3]{\pi} = 1.464\ 592\dots\dots\dots$	0.165 7166
$1 + \pi = 0.318\ 309\ 866\dots\dots\dots$	1.502 8501
$1 + 2\pi = 0.159\ 154\ 933\dots\dots\dots$ Aprx. $\frac{8}{5} \div 10$	1.201 8201
$1 + 4\pi = 0.079\ 577\ 47\dots\dots\dots$ Aprx. $\frac{8}{100}$	2.900 7901
$10 \div 4\pi = 0.795\ 774\ 7\dots\dots\dots$ Aprx. $\frac{8}{10}$	1.900 7901
$10 \div 8\pi = 0.397\ 887\ 3\dots\dots\dots$ Aprx. $\frac{4}{10}$	1.599 7601
$1 + \sqrt{\pi} = 0.564\ 189\ 6\dots\dots\dots$	1.751 4251
$1 + \sqrt[3]{\pi} = 0.682\ 784\ 1\dots\dots\dots$	1.834 2834
$\text{Log } \pi = 0.497\ 149\ 872\ 694\ 133\ 854\ 35\dots\dots$	
$\text{Log}_e \pi = 1.144\ 729\ 885\ 849\ 400\ 174\ 14\dots\dots$	
$\pi = 180^\circ$ considered as an angle.	
$\pi/180 = 0.017\ 453\ 29\dots\dots\dots$	2.241 8774
$\pi/360 = 0.008\ 726\ 65\dots\dots\dots$	3.940 8474
$180/\pi = 57.295\ 779\ 5\dots\dots\dots$	1.758 1226
$360/\pi = 114.591\ 559\ 0\dots\dots\dots$	2.059 1526

USEFUL NUMBERS.

	Logarithm
$\sqrt{2} = 1.414\ 21\dots\dots\dots$ Aprx. $\frac{1}{4} \times 10$	0.150 5150
$\sqrt{3} = 1.732\ 05\dots\dots\dots$ Aprx. $\frac{7}{4}$	0.238 5606
$\sqrt[3]{2} = 1.259\ 92\dots\dots\dots$ Aprx. add $\frac{1}{4}$	0.100 3433
$\sqrt[3]{3} = 1.442\ 25\dots\dots\dots$ Aprx. $\frac{1}{4} \times 10$	0.159 0404
$\sqrt[3]{4} = 1.587\ 40\dots\dots\dots$ Aprx. $\frac{8}{5}$	0.200 6867

SYSTEMS OF LOGARITHMS.

The logarithm [log] of a given number is the exponent which denotes the power to which a certain fixed numerical base is raised, in order to produce this given number. Thus if the base is 10, then the log of 100 is 2, because 10 raised to the 2d power=100. To multiply two numbers, add their logs; to divide, subtract the log of the divisor from that of the dividend; then from the resulting log find the corresponding number.

Log or $\log_{10}$ means the common, usual, or Briggs' logarithm; the base of this system is 10.

$\log_e$ or $\ln$ means the Napierian, natural, or hyperbolic logarithm; the base of this system is about 2.718 (see below), generally denoted by e .

Log of 1=0 in any system.

Log of base=1 in its own system.

e =base of Napierian, natural, or hyperbolic logarithms.

$e=2.718\ 281\ 828$.

$\log_{10}$ of $e=0.434\ 294\ 481\ 903\ 252$.

$\log_e$ of $e=1$.

10=base of usual, common, or Briggs' logarithms.

$\log_e$ of 10=2.302 585 092 994 046.

$\log_{10}$ of 10=1.

$\log_e 10 \times \log_{10} e=1$.

The modulus of any system is the constant by which the Napierian logarithm of a number must be multiplied to give the logarithm of the number in that system. The modulus of any system is equal to the reciprocal of the Napierian log of the base of that system.

Modulus of Napierian system= $1 \div \log_e$ of $e=1$.

Modulus of common system= $1 \div \log_e$ of 10=0.434 294 481 903 252.

The logarithm of a number (n) in any system is equal to the modulus of that system multiplied by the Napierian logarithm of the number. Or:

$\log_{10} n$ =modulus (common system) $\times \log_e n$.

$\log_e n$ =modulus (Napierian system=1) $\times \log_e n$.

To change a logarithm from the common to the Napierian system, or the reverse:

Common log $\times 2.302\ 585\ 092\ 994\ 046$ =Napierian log.

Napierian log $\times 0.434\ 294\ 481\ 903\ 252$ =common log.

ACCELERATION OF GRAVITY [g].

(See also table, pp. 87, 88.)

	Logarithm
$g=9.805\ 966$ meters per second per second. Aprx. 10.....	0.991 4904
$\sqrt{2}g=4.428\ 54$ in meters per second per second. Aprx. $\frac{1}{2}\times 10$.	0.646 2602
$g=32.171\ 7$ feet per second per second. Aprx. 32.....	1.507 4746
$\sqrt{2}g=8.021\ 44$ in feet per second per second. Aprx. 8.....	0.904 2523

MECHANICAL EQUIVALENT OF HEAT [M].

(See also p. 72.)

$M=426.900$ kilogram-meters per kilogram calorie.	
Aprx. $\frac{3}{4}\times 1\ 000$	2.630 3262
$1+M=0.002\ 342\ 47$ in same units. Aprx. $\frac{1}{3}+1\ 000$	3.369 6738
$M=778.104$ foot-pounds per pound Fahrenheit heat-unit.	
Aprx. $\frac{1}{2}\times 1\ 000$	2.891 0379
$1+M=0.001\ 285\ 17$ in same units. Aprx. $\frac{1}{4}+1\ 000$	3.108 9621
(For further reduction factors see table of measures of Energy, pp. 74-77.)	

SPECIFIC HEAT OF WATER.

(See also p. 72.)

Specific heat of water:

=4 186.17 joules per kilogram calorie. Aprx. 4 200..... 3.621 8166

Specific heat of water (in joules per kg cal)=mechanical equivalent of heat (in kilogram-meters per kilogram calorie)
 $\times$ acceleration of gravity (in meters per second per second).

MISCELLANEOUS FOREIGN MEASURES.

The following list of miscellaneous measures used in foreign countries was received too late for classification with the others. The values are taken from the November, 1903, issue (No. 278, vol. 73) of the *Monthly Consular Reports* published by the Department of Commerce and Labor of the U. S. Government. They are the measures which are referred to in the *Consular Reports*. Many of them are presumably only approximately correct. They have been rearranged here in the alphabetical order of the names of the countries. For an alphabetical list of the names of the measures see the index.

Argentine Republic. 1 pie=0.947 8 foot. 1 vara=34.120 8 inches. 1 cuadra=4.2 acres. 1 frasco=2.509 6 quarts. 1 baril=20.078 7 gallons. 1 libra=1.012 7 pounds. 1 arroba (dry)=25.317 5 pounds. 1 quintal=101.42 pounds.

Belgium. 1 last=85.134 bushels.

Bolivia. 1 marc=0.507 pound.

Borneo. 1 picul=135.64 pounds.

Brazil. 1 arroba=32.38 pounds. 1 quintal=130.06 pounds.

Celebes. 1 picul=135.64 pounds.

Central America. 1 vara=32.87 inches. 1 centaro=4.263 1 gallons. 1 fanega (dry)=1 574 5 bushels. 1 libra=1.043 pounds.

Chile. 1 vara=33.367 inches. 1 fanega (dry)=2.575 bushels. 1 libra=1.014 pounds. 1 quintal=101.41 pounds.

China. 1 tsun=1.41 inches. 1 chih=14. inches. 1 li=2 115. feet. 1 catty=1½ pounds. 1 picul=133½ pounds.

Cochin-China. 1 tael=590.75 grains.

Costa Rica. 1 manzana=1½ acres.

Cuba. 1 vara=33.384 inches. 1 arroba (liquid)=4.263 gallons. 1 fanega (dry)=1.599 bushels. 1 libra=1.016 1 pounds. 1 arroba (dry)=25.366 4 pounds.

Curacao. 1 vara=33.375 inches.

Denmark. 1 mil (geographical)=4.61 miles. 1 mil=4.68 miles. 1 tondeland=1.36 acres. 1 tonde (cereals)=3.947 83 bushels. 1 centner=110.11 pounds.

Egypt. 1 pic=21½ inches. 1 feddan=1.03 acres. 1 ardeb=7.690 7 bushels. 1 oke=2.722 5 pounds.

Greece. 1 drachme=a half ounce (presumably av.). 1 livre=1.1 pounds. 1 oke=2.84 pounds. 1 quintal=123.2 pounds.

Guiana. 1 livre=1.079 1 pounds.

Holland. 1 last=85.134 bushels.

Honduras. 1 milla=1.149 3 miles.

Hungary. 1 oke=3.081 7 pounds.

India. 1 bongkal=832. grains. 1 seer=1 pound 13 ounces. 1 maund=82½ pounds. 1 candy (Madras)=500. pounds. 1 candy (Bombay)=529. pounds.

Isle of Jersey. 1 vergées=71.1 square rods.

Japan. 1 bu=0.1 inch. 1 sun=1.193 inches. 1 shaku=11.930 5 inches. 1 ken=6 feet. 1 tsubo=6 feet square. 1 se=0.024 51 acres. 1 tan=0.25 acre. 1 sho=1.6 quarts. 1 to=2 pecks. 1 koku=4.962 9 bushels. 1 catty=1.31 pounds. 1 picul=133½ pounds.

Java. 1 catty=1.35 pounds. 1 picul=135.1 pounds.

Luxemburg. 1 fuder=264.17 gallons.

Malta. 1 caffiso=5.4 gallons. 1 barrel (customs)=11.4 gallons. 1 cantaro (cantar)=175. pounds. 1 salm=490. pounds.

Mexico. 1 vara=33. inches. 1 frasco=2.5 quarts. 1 fanega (dry)=1.547 28 bushels. 1 libra=1.014 65 pounds. 1 quintal=101.41 pounds. 1 carga=300. pounds.

Morocco. 1 artel=1.12 pounds. 1 fanega (dry) strike=70. pounds. 1 cantar=113. pounds. 1 fanega (dry) full=118. pounds.

Newfoundland. 1 quintal (fish)=112. pounds.

Nicaragua. 1 manzana=1½ acres. 1 milla=1.149 3 miles.

Palestine. 1 rotte=6 pounds.

Paraguay. 1 vara=34. inches. 1 cuadra=78.9 yards. 1 cuadra square=8.077 square feet (?). 1 league (land)=4 633. acres. 1 arobe=25. pounds. 1 quintal=100. pounds.

Persia. 1 batman (tabriz)=6.49 pounds.

Peru. 1 vara=33.367 inches. 1 libra=1.014 3 pounds. 1 quintal=101.41 pounds.

Philippine Islands. 1 picul=137.9 pounds.

Portugal. 1 almuda=4.422 gallons. 1 arratel=1.011 pounds. 1 libra=1.011 pounds. 1 arroba (dry)=32.38 pounds.

Russia. 1 arshine (square)=5.44 square feet. 1 vedro=2.707 gallons. 1 korree=3.5 bushels. 1 chetvert=5.774 8 bushels. 1 klafter=216. cubic feet. 1 funt=0.902 8 pound. 1 pood=36.112 pounds. 1 berkovets=361.12 pounds.

Russian Poland. 1 vlocka=41.98 acres. 1 garnice=0.88 gallon. 1 last=11 $\frac{1}{2}$ bushels.

Salvador. 1 manzana=1 $\frac{1}{2}$ acres.

Sarawak. 1 coyan=3 098. pounds.

Siam. 1 catty=1.35 pounds. 1 coyan=2 667. pounds.

Spain. 1 pie=0.914 07 foot. 1 vara=0.914 117 yard. 1 arroba (liquid)=4.263 gallons. 1 fanega (liquid)=16. gallons. 1 butt (wine)=140. gallons. 1 dessiatine=1.599 bushels. 1 libra=1.014 4 pounds. 1 arroba (dry)=25.36 pounds. 1 frail (raisins)=50. pounds. 1 barrel (raisins)=100. pounds. 1 last (salt)=4 760. pounds.

Sumatra. 1 bouw=7 096.5 square meters. 1 catty=2.12 pounds.

Sweden. 1 tunna=4.5 bushels. 1 pund=1.102 pounds. 1 centner=93.7 pounds.

Syria. 1 rottle=5 $\frac{1}{2}$ pounds. 1 quintal=125. pounds. 1 cantar (Damascus)=575. pounds.

Turkey. 1 pik=27.9 inches. 1 oke=2.828 38 pounds. 1 cantar=124.703 6 pounds.

Uruguay. 1 cuadra=nearly 2 acres. 1 suerte=2 700. cuadras. 1 fanega (single)=3.888 bushels. 1 fanega (double)=7.776 bushels. 1 libra=1.014 3 pounds.

Venezuela. 1 vara=33.384 inches. 1 fanega (dry)=1.599 bushels. 1 libra=1.016 1 pounds. 1 arroba (dry)=25.402 4 pounds.

Zanzibar. 1 frasila=35. pounds.

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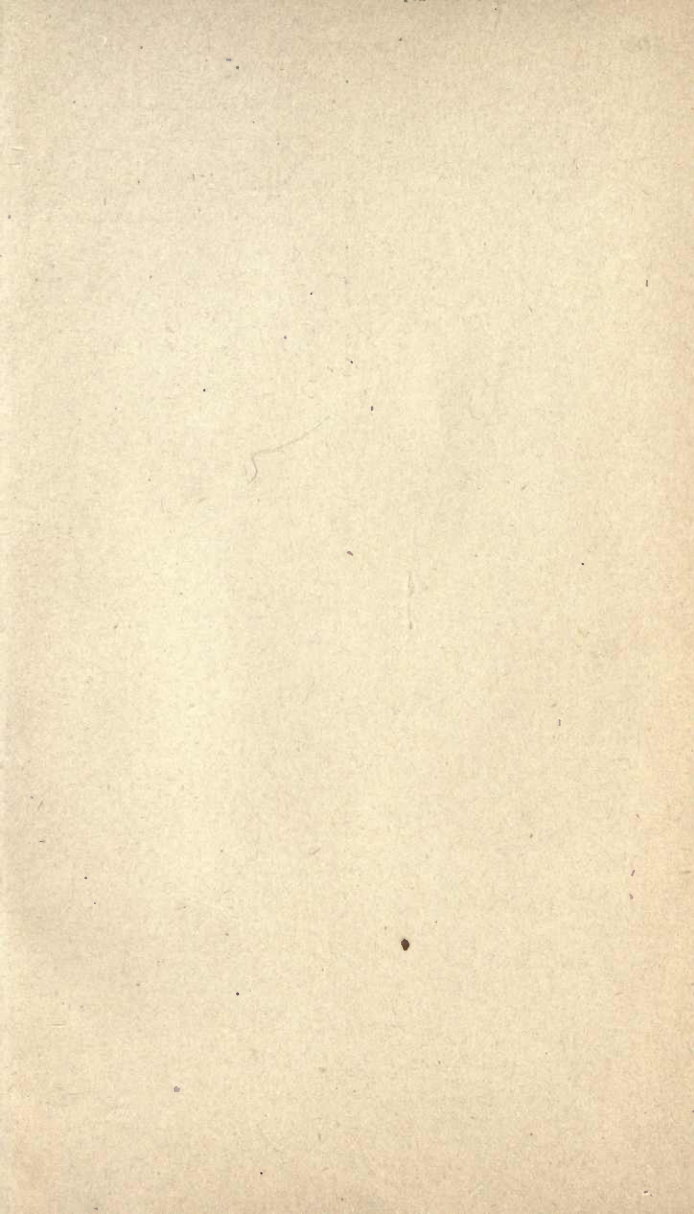
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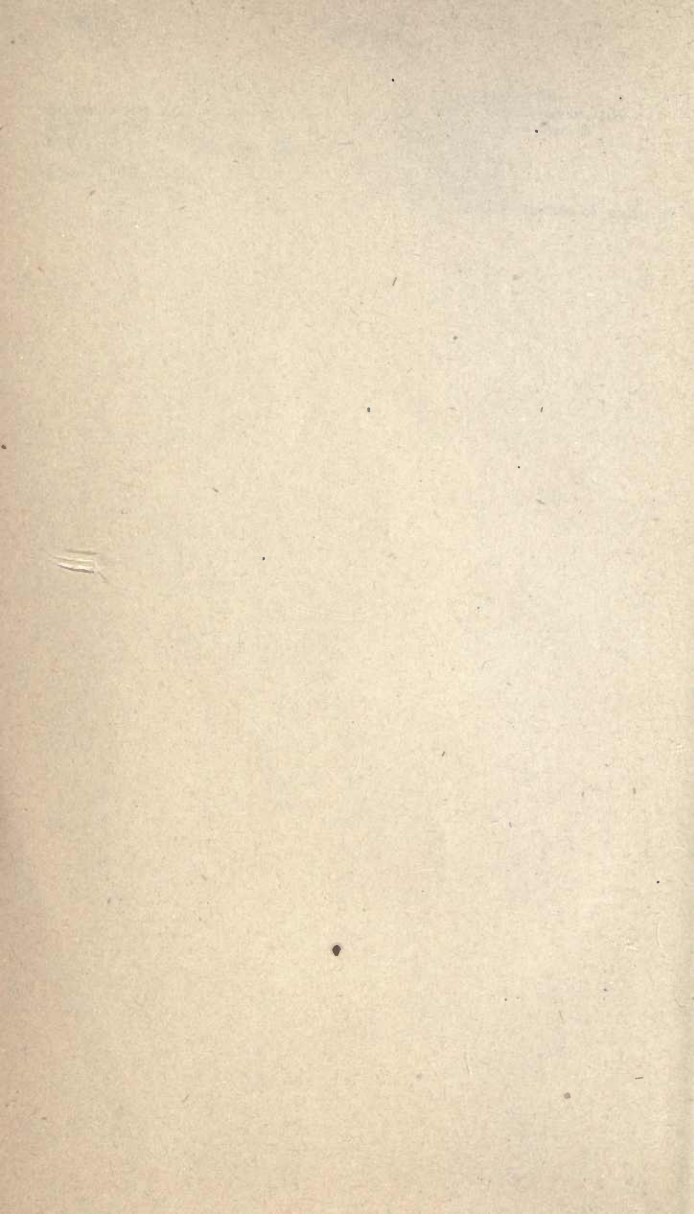
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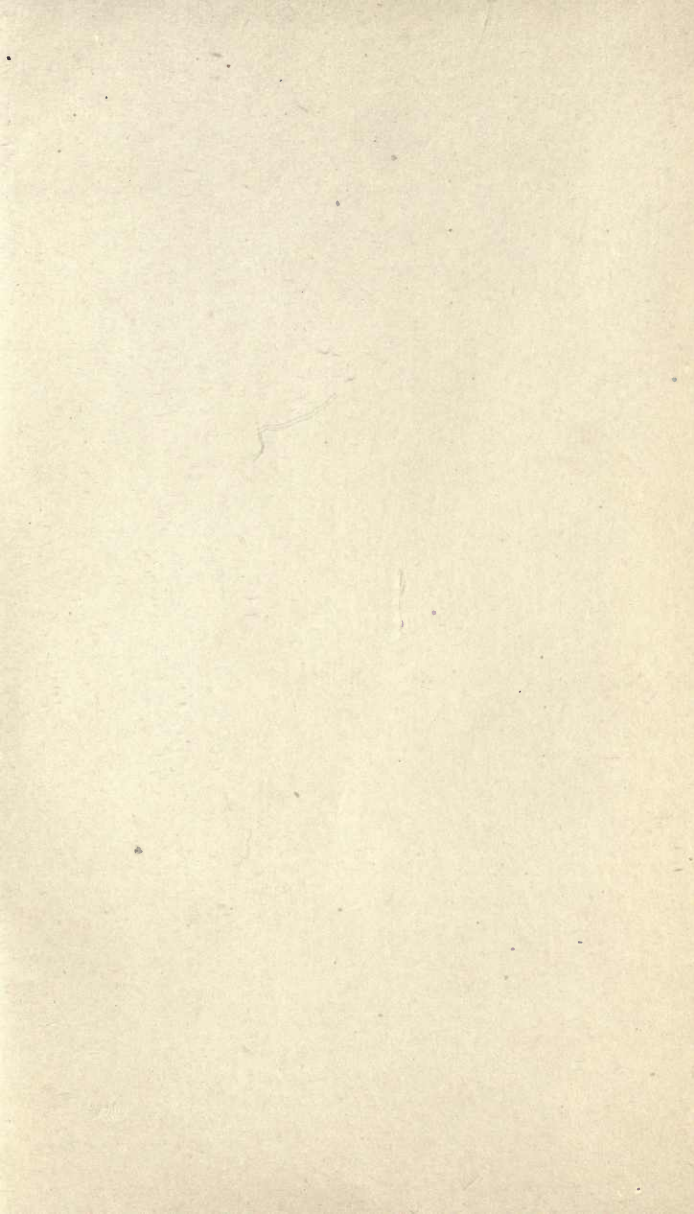
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$\frac{0}{00}$ grades, 90

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